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GLOBAL TRENDS IN POPULATION AND RESOURCES

HEARING

BEFORE THE

SUBCOMMITTEE ON INTERNATIONAL ECONOMIC POLICY

OF THE

COMMITTEE ON FOREIGN RELATIONS UNITED STATES SENATE

NINETY-SEVENTH CONGRESS

SECOND SESSION

JUNE 23, 1982

Printed for the use of the Committee on Foreign Relations

U.S. GOVERNMENT PRINTING OFFICE
96-841 O WASHINGTON : 1982

5381-10

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GLOBAL TRENDS IN POPULATION AND RESOURCES

WEDNESDAY, JUNE 23, 1982

UNITED STATES SENATE,
SUBCOMMITTEE ON INTERNATIONAL
ECONOMIC POLICY OF THE
COMMITTEE ON FOREIGN RELATIONS,
Washington, D.C.

The subcommittee met, pursuant to notice, at 10:12 a.m., in room 4221, Dirksen Senate Office Building, Hon. Charles McC. Mathias, Jr. (chairman of the subcommittee) presiding.

Present: Senators Mathias, Pell, and Dodd.

Senator MATHIAS. The subcommittee will come to order.

This morning, the Subcommittee on International Economic Policy will receive testimony on the important and, at least to the chairman, intriguing subject of global trends in population and resources. A number of forecasts of global trends in population, resources, economic growth, and environmental conditions have been produced in recent years. The "Global 2000 Report" prepared during the administration of President Carter by an interagency task force of experts is one of the better known efforts to use global models to assess the trends decades into the future.

The findings of the "Global 2000 Report" and other studies of global trends have been controversial, and I suppose that is to be expected. Whether the anticipated conditions are considered too pessimistic or whether they are considered too optimistic, I think they are certainly of enormous interest to every one of us.

The basic question, and the one that I hope will provide us with our focus for the hearing this morning is whether global modeling of trends in population and resources is sufficiently useful to deserve greater attention and coordinated preparation within the Federal Government. I am interested in the uses which are being made or the uses which could be made or the uses which ought to be made of global modeling in anticipating foreign policy problems.

Our witnesses this morning are very well qualified to address this subject. Later this morning, we will receive testimony from the chairman of the Council on Environmental Quality, A. Alan Hill. Following Mr. Hill's testimony, we will hear from Gus Speth and Elliot Richardson. Mr. Speth was the chairman on the Council of Environmental Quality when the "Global 2000 Report" was prepared, and is currently president of the Institute for World Environment and Resources. Mr. Richardson's wide experience in government services is well known. In fact, he is noted in the "Guinness Book of Records" as the only person to hold four different cabinet positions in the U.S.

Government, but of course his record of public service goes well beyond the Cabinet. He appears today as a private citizen, and as a member of the Year 2000 Committee.

To start off our hearing, we are privileged to have Dr. John H. Gibbons, director of the Office of Technology Assessment [OTA], who will present a report prepared by OTA entitled "Global Models, World Futures, and Public Policy: A Critique." But before I call on Dr. Gibbons, let me yield to the distinguished Senator from Rhode Island.

Senator PELL. Thank you, Mr. Chairman.

I am particularly interested in this morning's hearing, and apologize for not being able to be here all morning. By coincidence, I have to meet with a delegation from my State concerned with the Hatch Act, and that is a compulsory matter for me to attend.

I am interested in this subject matter very much, ever since I used to go off with Constantinos Doxiadis on his symposions, and here I would add that this word has a Greek "o-n" ending, not the Latin "u-m." The Latin "u-m" is an exchange of ideas, as you know. "O-n" means an exchange of ideas accompanied by wine, song, and a degree of frivolity. His thinking and his science of ekistics led directly into the Club of Rome, of which I am very proud to be a member—I am one of seven American members. The Club of Rome has relied a great deal on global modeling, global models, and I remember when the limits to growth model came out about 10 years ago, there was a great deal of criticism of it for being overly gloomy, and it may have been a bit gloomy, because the authors did not take into account some of the positives in life. It was based on a worst case scenario.

But then, 3 years later, in Berlin, we put out another report called "Mankind at the Turning Point," which was of a much more positive nature. I think we should bear in mind that nations are really like human beings in many ways. You hope you grow to a certain extent and then stop growing, not get inflated, and by the same token, a human being, you hope, while not expanding in size, continues to develop in mind and heart and soul, quality of life that that human being leads. Nations, too, can expand to a certain degree, but after you get to that degree, x television sets, x this, x that, then you would hope the expansion physically would stop, and the emphasis would be on the quality of education, the quality of facilities for enjoyment and for productive enjoyment that are made available to that community.

I think the Mankind at the Turning Point report was remarkably significant, and went remarkably unnoticed in the world as a whole. I would be interested in your commenting on this. I will not be able to hear your words myself, since I have to leave, but I would look forward to reading the record. I would also hope, Dr. Gibbons, that you might touch on what you consider to be the most useful mission we of the Club of Rome can continue to have in the coming years. Having put out these reports, we are now under the leadership of our guru, Orelio Peccei, somewhat looking in the direction where we can be the greatest help to the world, and where we cannot only analyze, as he calls it, the problematique, but also come up with solutions to the problematique.

Thank you, Mr. Chairman.

Senator MATHIAS. Thank you, Senator Pell.

Senator PELL. That must have sounded like double Dutch, because I think only those of us who are in the Club of Rome must have understood some of my phraseology.

Senator MATHIAS. Thank you very much. We are glad to have your interest and participation.

Since the "Global 2000 Report," as I said, has been somewhat controversial, I think it is valuable that we have your particular expertise and experience on this committee at a time when we are looking at these reports and looking at this whole science and how it may affect decisions in public policy and particularly in the formulation of foreign policy.

Dr. Gibbons, we are delighted to have you here this morning. We are pleased to receive your report, the OTA report on global models. I understand that it will be available to the public, and I hope other witnesses will be able to comment upon it. We will be glad to have your statement at this time.

STATEMENT OF JOHN H. GIBBONS, DIRECTOR, U.S. CONGRESS, OFFICE OF TECHNOLOGY ASSESSMENT, ACCOMPANIED BY PAUL PHELPS, ANALYST

Mr. GIBBONS. Thank you. Mr. Chairman and Senator Pell.

I am pleased to bring with me today Mr. Paul Phelps, who directed the OTA critique of world models.

In preparing my remarks today and the written testimony which I have submitted for the record, we have drawn on this report on "Global Models, World Futures, and Public Policy" and also, Mr. Chairman, on other studies at OTA, including some extensive work on energy supply and use, our recently completed assessment of "World Population and Fertility Planning Technologies" and a number of current projects, for example, on land productivity, critical materials, tropical forests, water availability, and international industrial competitiveness.

OTA's central responsibility is to apply analytical methods to the examination of technology as it affects and is affected by society. We work on issues of immediate concern to Congress, such as acid rain or technology transfer to the Soviet Union, but we also try to provide foresight on emerging issues, such as rapid advances in molecular biology or the future availability of strategic materials.

OTA is pleased to participate in these hearings about improved analysis and understanding of global trends in the areas of population, resources, environment, and economic growth. We are particularly interested because these subjects are interrelated, they are all strongly affected by technological innovation, and they are important factors in achieving the U.S. foreign policy assistance goal of encouraging self-sustaining growth and development.

The United States has at least two reasons to be deeply interested in global trends. First is economic self-interest. We depend increasingly upon the entire world for resources to sustain our economy, both for the acquisition of raw materials and for markets in which to sell our products. Second is a broader sense, that of broader social self-interest. Our Judeo-Christian tradition has long nourished the belief that caring for other nations is a good thing. If we want to transform this belief into

effective policies and programs, then we need to test our charitable instincts dispassionately to see whether or not our actions are taking us toward the broad goals of U.S. development assistance.

During the next 20 years, the world's population will probably increase by more than 2 billion people. The gap between the incomes of rich and poor nations may increase. Energy and food prices could rise rapidly. Industrial activity could alter world weather patterns and change the productivity of key agricultural regions around the world. Vast areas of valuable farmland may be lost to erosion, desertification, and urban sprawl. Forty percent of the world's tropical forests may be destroyed, and nearly a third of all the world's plant and animal species may be lost.

For most of our history, the resources and isolation of the United States have shielded us from the miseries experienced elsewhere on the globe, but it would be impossible for us to escape the consequences of global changes of such magnitude as I have mentioned. Our access to key resources and markets for our products could be restricted, and widespread hunger elsewhere in the world could place unprecedented stress on marginal U.S. agricultural lands. And of course we would be unable to escape the effects of worldwide climatic changes.

Now, I am not reciting these problems as a prophet of doom. On the contrary, I am personally optimistic about the ability of human resourcefulness to solve big problems if they are recognized in time, but I am not convinced that our past methods of analysis will be sufficient to the issues of the present and the future. The scale, complexity, and gravity of these issues demand new approaches.

Organized thinking can be very productive even in the absence of good data. The Greeks made substantial progress in a number of intellectual fields without much recourse to data or to experimental testing. They built logical or intuitive models of many things from atoms to social organizations. But when data and experiments were combined with logical thinking, the results were the great advances that have culminated in modern science, medicine, and technology. Since that time, a great variety of models has emerged—mental models, physical models, mathematical models.

By models, we mean representations or simulations of systems or processes. Models are analytic tools that are used to combine and interrelate data, to discern underlying principles, to identify, follow, and project trends, and to test assumptions in a self-consistent framework. The comparatively recent advent of electronic computers has enabled enormously numerous and complex bits of information to be taken into account simultaneously.

Hundreds of models are relevant to the issues that this committee is addressing today, but many of these models are relatively limited and specific. Consider, for example, the subject of natural resources: There are models that focus on a single region or single type of resource; some models are based on principles of science; others are based on engineering or economic principles. These specialized models can be very useful for aggregating data and integrating information on specific policy questions, but as the economics and environments of nations and large regions of the world become increasingly interconnected, it becomes more useful if not essential to examine these systems in a more global context.

This has led to the recent attempts to build so-called "global-models." There is a variety of global models, some specialized, some general. A lot of attention is being given to developing a specialized "global carbon dioxide" model, for example, although this is only one of several concerns about our atmosphere. We now know that human activities are causing substantial changes in the chemical composition of the Earth's atmosphere, and that these changes could have a profound worldwide impact over the coming century on climate, food production, and human health. It is hoped that this carbon dioxide model will help scientists to improve their understanding about the sources, movement, and fate of carbon dioxide, and then to better predict how its buildup might affect, for example, monsoon patterns and the melting of polar icecaps.

There have been even bolder attempts to use more general global modeling to describe the interactions of such phenomena as population, enviroment, resources, and economic growth. It is admittedly very difficult to gain a good understanding about any one of these parameters. Much of the needed data are poor, and many of the factors that influence the individual phenomena are poorly understood. It is even more difficult to interrelate these separate phenomena, so as to gain some sense of the whole or the total effect. I am reminded of a cartoon that shows a road sign that reads "Entering Hillsville: Founded 1802, altitude 620, population 3,700; total, 6,122."

Mathematics is a valuable aid to thought, Mr. Chairman, but statistics should not be used as a substitute for logic. In shaping policy, global models have a role, but not a central one. The hope is that global modeling may be able to provide a broader context into which more practical and specialized analyses can be fitted and tested.

Now, as to the findings about global models, Mr. Chairman, the five model studies that were examined by OTA demonstrated at least three fundamentally different predictive styles. Two of the studies, including the "Global 2000 Study" conducted by the U.S. Government, examined what might happen if recent trends continue into the future. Two others look at the altered outcomes that might be achieved, assuming significant departures from current trends. And the fifth model examines the policies and actions that might bring those changes about.

Although these differences make it difficult to directly compare the projections of these models, the five studies do agree on the following points. First, despite some encouraging changes, the continuation of recent trends will result in growing environmental, economic, and political difficulties. The next two or three decades will be a period of fateful transition, as the world's socioeconomic and biological systems undergo major changes. The outcome is not preordained, however. The future shape of the Earth's economy and its environment depends a great deal upon decisions being made now and over the next several years.

Second, there is no technical or physical reason why the very basic human needs—food, clothing, and shelter— cannot be supplied to all the world's people, both now and for a long time to come, if the problem of unequal distribution can be remedied. However, population and economic activity cannot grow indefinitely without eventually causing widespread hunger and resource scarcities.

Third, regional crises of global significance are far more likely than a widespread global collapse. While world food production is growing in the aggregate, for example, per capita food supply is beginning to lose ground in regions like South Asia and Sub-Saharan Africa, where population growth rates are very high. Other potential resource and pollution problems, even the CO_2 "greenhouse effect," if it occurs, will also be highly regional in their most serious impacts.

Fourth, and finally, some of the most promising strategies for influencing parameters like population, agriculture, and energy, will require decades of work before substantial changes can be induced. Actions initiated soon are likely to be more effective and less costly than the same set of actions taken later, and some actions may not work at all if they are postponed too long.

Mr. Chairman, you mentioned an interest in global trends. I would like to spend a few moments with you this morning on several specific trends that have been examined in OTA studies. First, I will address population.

Although average population growth rates are now beginning to decline in the world, some of the poorest nations still have population doubling times as short as 18 years. This creates considerable momentum for future growth: More than 90 percent of the global population growth between now and the end of the century will occur in third world countries, where resource problems such as poor soil quality, already severely constrain comparable growth in food production.

Technology is both a cause of and a potential solution to population growth, but any solution must involve social change. Thus, improved health care and sanitation have cut death rates quickly, but technology affects birth rates more slowly because the use of birth control technologies is more closely tied to long-standing cultural values and practices. If people had easier access to birth-control technologies, the world population in the year 2000 could be closer to the lower estimate of 5.9 billion people than the higher estimate of 6.5 billion people. The difference between these two projections is roughly equal to the current population of all of Africa.

It is heartening to note that most nations with high population growth rates now recognize that it is in their self-interest to lower their growth rates. At the same time, the record of actual implementation of such programs is quite mixed. Growth rates are markedly lower in China and in some other Asian nations, for example, but they remain high in the Arab States and in parts of the Caribbean, Central America, Sub-Saharan Africa, and elsewhere.

The second trend I would like to address is that of resources. The richest concentrations of many nonrenewable resources such as oil and metals are rapidly being depleted, but this loss is partially offset by improved technology for exploration and production from lower-grade deposits. Advancing technology also provides many opportunities to substitute more common materials for less common ones, and to use less materials in providing needed goods and services.

The Earth's concentration of renewable resources such as forests, grasslands, and farmlands are also distributed unevenly. Although these resources are considered renewable, their actual renewability can be destroyed where they are mismanaged or overstressed.

These points mean that resources should not be thought of strictly in terms of deposits of coal or acres of land, but increasingly as reflections of the state of technology and the extent of wise management. Given this potentially good news—that is, that the availability of resources is subject to human influence—we must add some caveats. First of all, high technology and innovative management of resources are certainly not universally available. Second, some resources, for example, the Ogallala aquifer in the Midwestern United States, are effectively substitutable only with massive capital investments.

Mr. Chairman, if there were more time this morning, I would make a few summary remarks about individual resources, such as food, water, energy, and the environment, but in the interest of time, I will leave those for the record.

Senator MATHIAS. Thank you very much, Dr. Gibbons.

Mr. GIBBONS. Mr. Chairman, one important implication that emerges from these trends is the need for improved Government foresight on global issues. To do better forecasting, we need three things. First of all, we need accurate and adequate data on relevant conditions in various regions. Second, we need an analytic capability, that is, experts in the relevant disciplines and agencies who can collect and interpret these data. And third, we need the analytic tools, such as computerized models, that will help analysts to organize the data, to explore alternative futures, and to present the results in ways that are useful to policymakers and planners.

A variety of models are already in use throughout the U.S. Government in a wide range of forecasting applications. The Joint Chiefs of Staff [JCS], for example, are developing a version of the World Integrated Model for use in their Joint Long-Range Strategic Appraisal. The same model has been used by both the Agriculture Department and the Bureau of Mines. Other Federal agencies, including CIA, EPA, DOE, and the Census Bureau routinely use regional or sectoral models in carrying out their long-range analysis and planning functions.

The Agency for International Development [AID] has used several models of population or resources, but on a nation-by-nation basis. The Global 2000 study made it clear, however, that there are deficiencies in the way this Government modeling capability is being used. Different agencies did not always use consistent assumptions about driving variables, such as the assumed rate of population growth and GNP, and some of the projections were made as if the resources could be counted on to achieve improvements in more than one consuming sector.

Proposals for improving the Government's modeling capability usually stress the need for a coordinated strategy involving complementary efforts at several levels. The proposed initiatives generally reflect three priorities. The first is to do a better job with current analytic tools. It could be very helpful if an interagency mechanism were established to share data and compare results between agencies and to assure consistency between their models. Such an effort could also enable those agencies, such as the Department of State, whose modeling capability is not so well developed, to have easier access to this technology.

The second is to support technical improvements in modeling. A group might be established within the executive branch to encourage third-party validation of existing models, to provide a global modeling forum at which modelers could exchange ideas and critique one another's work, and stay in contact with modeling work being done outside the United States.

Third is to link foresight with policymaking. Congress may wish to coordinate and upgrade the foresight capabilities of its legislative research agencies, or it could choose to create a new executive branch unit for this purpose. The functions of such a new unit might be to provide the President, the Congress, and other decisionmakers with thorough analyses and a broad range of options on global issues; or to prepare a report on global trends and prospects, to be delivered biennially by the President to the Congress; or perhaps, in conjunction with the Department of State, to encourage similar assessments of long-range issues by other nations and to support the data-gathering and analytic activities of the United Nations, international financial institutions, and nongovernmental organizations.

Mr. Chairman, the traditional approach to long-range planning has been that we will muddle through somehow, but there is good reason to believe that the time has run out on this venerable attitude. The dilemmas I have outlined this morning are unprecedented in scale. The problems are also emerging at an unprecedented rate. Unlike the past, there will be no easy escape by finding areas with new resources.

We are beginning to approach the global limits in oil, gas, fresh water, arable land, and other resources. Our present system is not sustainable, and the mathematics of accelerating growth are catching up with us. Many of the most sensible solutions will take years or decades to have an effect, and in some areas we don't have the luxury of waiting that long. It simply may not be possible to solve many global problems with bandaids once the hemorrhages have actually begun. Muddling through may work a little longer, but I for one would not like to take that chance.

Thank you, Mr. Chairman.

[Mr. Gibbons' prepared statement follows:]

PREPARED STATEMENT OF JOHN H. GIBBONS

GLOBAL TRENDS IN POPULATION, RESOURCES, AND ENVIRONMENT

Introduction

Mr. Chairman and Members of the Committee, I appreciate the opportunity to participate in these hearings today. In preparing my remarks and the written testimony which I submit for the record, I have drawn partly upon OTA's critique of Global Models, World Futures, and Public Policy, which is being released today, and partly upon other OTA reports relevant to these discussions, including our recently completed assessment of World Population and Fertility Planning Technologies: The Next Twenty Years. Finally, I have not been able to resist drawing upon my own past experiences related to the subjects of energy, resources, environment, and development.

One of OTA's central responsibilities is to apply analytical methods to the examination of technology as it affects, and is affected by, society. We work on issues of immediate concern to Congress, such as acid rain or nuclear waste, but we also provide foresight on emerging issues, such as rapid advances in molecular biology or the implications of advanced technologies for the future availability of strategic materials. As a consequence of these responsibilities, OTA must deal daily with a great variety of data acquired from diverse sources.

It must analyze the data using experts of various sorts, and integrate the resulting information using a variety of tools and techniques, including "models." By models we mean representations or simulations of things, systems, or processes They are analytic tools used to combine and interrelate data; to discern underlying principles; to identify, follow, and project trends; and to provide a consistent way of testing the sensitivity of eventual outcomes to differing assumptions about the factors that affect them.

While OTA's work focuses primarily on domestic issues, these are increasingly imbedded in an international context of science and technology, trade, resources, and other factors. We were therefore pleased to be invited to participate in these hearings about the status and outlook for improved analysis and understanding of global trends in such areas as population, resources, environment, and economic growth. These subjects have several commonalities: They are interrelated; they are all intimately affected by technological innovation; and they are important factors in achieving the goal of self-sustaining growth and development.

The United States has at least two reasons to be deeply interested in both global trends and improved methods for understanding their dynamics and details. First, economic self-interest. We depend increasingly upon the entire world for resources to sustain our economy, both for the acquisition of raw materials and for markets in which to sell our products. This provides a very strong incentive for knowing how the world is getting along, where it is heading, and how we might improve our lot. That means looking at regions and resources that may, at first glance, seem to have little immediate importance for us. Take, for example, tropical forests. Their loss may seem unfortunate to us, but not critical; yet it could also mean fewer resources for such items as pharmaceuticals and wood products. Such a loss may also mean slower economic growth in the affected countries and therefore a reduced opportunity for them to purchase U.S. exports in the future. Second, broader social self-interest: Our Judeo-Christian tradition has long nourished the belief that caring about other peoples is a good thing. If we intend this caring process to be effective, then we need to test our charitable notions against dispassionate analysis to see whether our actions are taking us toward broad goals such as freedom, justice, and self-sustaining economic development.

In other words, we have a need for methods and procedures to help us understand global trends—methods that will allow us use both our hearts and our heads in our international affairs, and help us design programs that satisfy both of these motives.

During the next 20 years, the world's population may increase by 2.4 billion, the gap between the incomes of rich and poor nations could increase, energy and food prices could rise rapidly, industrial activity could alter world weather patterns and change the productivity of key agricultural regions, vast areas of valuable farmland could be lost to erosion, desertification, and development, 40 percent of world's tropical forests could be destroyed, and nearly a third of all the world's plant and animal species could be lost. It would be impossible for the United States to escape the consequences of global changes of such magnitude. For most of our history the vast resources and isolation of a bountiful continent shielded us from miseries experienced elsewhere on the globe, but the rules are changing rapidly. Our access to key resources and markets for our products could be restricted, and widespread hunger could place unprecedented stress on marginal U.S. agricultural lands. And of course we would be unable to escape the effects of worldwide climatic changes.

I am not reciting these problems as a prophet of doom—on the contrary, I am an optimist about the ability of human resourcefulness to prevail even against problems of the potential dimensions I've outlined. I am raising the issue because it is likely that they will not be solved using conventional approaches and I am concerned by the lack of a systematic approach for resolving them.

Data, analysis, and modeling

Logical, organized thinking can be very helpful, even in the absence of a lot of data. The Greeks made substantial progress in a number of intellectual fields without much recourse to data or experimental testing. They built logical or intuitive "models" of many things, from atoms to social organizations. But when data and experiments were combined with logical thinking, the results were the great advances that have culminated in modern science, medicine, technology. Since that time a wide variety of models has emerged—mental, physical, mathe-

matical. The comparatively recent advent of electronic computers has enabled enormously numerous and complex bits of information to be taken into account simultaneously.

With respect to the issues your Committee is addressing, there probably exist thousands of relevant models. Many of them are relatively limited and specific. Consider, for example, natural resources: there are models that focus on a single region or type of resource; some models are based on physical/chemical/geological principles; others are based on engineering or econometric theory. These specialized models can be very useful for aggregating data and integrating information on specific questions such as trade or investment.

But as the economies and environments of different nations and regions become increasingly interconnected, it becomes useful, if not essential, to examine systems in a more global context, as well as in their particulars. This has led to the recent attempts to build "global" models as a framework for examining globally interrelated topics such as resources, population, and environment.

There is a great variety of such "global" models. For example, we now recognize that human activities are causing substantial changes in the chemical composition of the earth's atmosphere, and that these changes may have a profound impact over the coming century on climate, food production, and human health. As a result, substantial attention is being given to developing a "global carbon dioxide" model, only one of many concerns about the atmosphere. It is hoped that the models will help scientists improve their understanding about the sources, movement, and fate of carbon dioxide and to be able to predict how it might affect, for example, monsoon patterns and the melting of polar icecaps. This would enable us to better understand the long-range consequences of the accelerated use of fossil fuels and other activities that contribute to higher levels of CO_2 in the global atmosphere.

There have been even bolder attempts to use global modeling to describe the interactions of such phenomena as population, environment, resources, and economic growth. It is admittedly very difficult to gain a good understanding about any one of these parameters. Much of the relevant data are poor, and many of the factors that influence the individual phenomena are frequently not well understood or even recognized as such. It is even more difficult to combine or interrelate the phenomena, such as the link between population growth and economic progress. I am reminded of a recent cartoon in the New Yorker, which shows a road sign that reads,

Entering Hillsville:

Founded	1802
Altitude	620
Population	3,700
Total	6,122

Plainly mathematics is a valuable aid to thought in a complicated area, but statistics should not be used as a substitute for logic. No global model will be capable of taking a view of the world broad enough to encompass all of the factors that may lead to critical problems or offer practical remedies; models taking all reasonable variables into account would be unmanageable. In addition, global models contain little representation of geopolitics, so it would be inappropriate to use them for forecasting short-term events that are more strongly affected by political variables. As a result, global modeling can be a useful input to long-range policy analysis, but it should not be—nor is it likely to become—the sole or even principal basis for decisionmaking. Global models can serve a critical role, however, by identifying areas where attention should be focused and by providing a broader context into which more "practical," specialized analyses can fit. They can also serve as a control that will force analysts and policymakers to be consistent in their assumptions. For instance, it is illogical to assume (as was apparently done in Global 2000) that the same barrel of oil or acre-foot of water can be available for several different uses by several different nations at the same time.

Global models and their findings

OTA has not directly used global models, but we have found both the models and their findings to be helpful in our analytic work. We are releasing today, in conjunction with these hearings, OTA's review of five major global modeling studies, including the Global 2000 Study concluded nearly 2 years ago by the U.S. Government. The findings of our review, broadly stated, are as follows:

(1) *Global modeling represents an important analytic tool* for exploring alternative world futures.

(2) Even at its current, relatively primitive state of the art, global modeling offers the U.S. Government a promising opportunity to improve its foreign capability, if the models are used judiciously and in combination with other analytic tools as inputs to policy development and long-range planning.

(3) Improvements in socioeconomic theory, modeling methodology, and data-gathering technology could substantially improve the usefulness of the projections generated by global models.

(4) Existing deficiencies in the Government's modeling capability are both institutional and technical in nature. Any effort to correct these deficiencies should include better coordination among Federal agencies and increased attention by modelers to the information needs of policymakers and decisionmakers.

The global modeling studies examined by OTA demonstrated at least three fundamentally different "predictive styles." Two of the models—World 3 (The Limits to Growth, 1972) and Global 2000—examine what might happen if recent trends continue. Two others—the Latin American World Model (Catastrophe or New Society, 1976) and the UN Input-Output Model (The Future of the World Economy, 1977)—look at the altered outcomes that might be achieved assuming broad changes from current trends. And the fifth—the World Integrated Model (Mankind at the Turning Point, 1974)—examines the policies and actions that might bring those changes about. These differences, as well as more specific differences in patterns of regionalization, degrees of aggregation, and assumptions about key parameters, make it difficult to compare their projections.

Despite these difference, however, the five models do show a limited consensus about the major forces that shape world trends and the identity of the problems faced in achieving human progress, as well as about some of the steps that might be taken to address them. In general, the models agree on the following points:

Population and physical capital cannot grow indefinitely on a finite planet without eventually causing widespread hunger and resource scarcities. However, there is no physical or technical reason why basic human needs—food, clothing, shelter—could not be supplied to all of the people now living in the world or even twice that number. These needs are not now being met because of an unequal distribution of resources and consumption—not because of overall physical scarcities.

Regional crises of global significance are far more likely than a widespread global collapse. (World food production is growing in the aggregate, for example, but per capita food production is losing ground in regions like South Asia and Sub-Saharan Africa, where population growth rates remain very high.) Other future resource and pollution problems are also likely to be regionally specific. Even in the case of the CO_2 "greenhouse" effect, the most serious impacts would be highly regional.

Despite some encouraging, important, and salubrious changes, the continuation of recent patterns and trends would result in growing environmental, economic, and political difficulties. "Business as usual," therefore, is not the path to a better world and not a likely course of action. The next two or three decades could therefore be a period of fateful transition as the world's socioeconomic and biological systems assume features that are critically different from the present. The outcome is not preordained, however—the future of the earth's economy and environment depends a great deal upon decisions and changes being made now.

Because of the complexity, momentum, and interdependence of the world's physical and socioeconomic systems, the full long-term effects of a given action are almost impossible to predict with precision or certainty. However, productive actions taken soon are likely to be more effective and less costly than the same set of actions taken later. Some of the most influential parameters, such as population, agriculture, and energy, require decades before substantial changes can occur. The models suggest that cooperative long-term approaches are more effective than short-term, competitive approaches.

Finally, some existing plans and agreements—particularly complex, long-term international development programs—are based on assumptions about the world that are either mutually inconsistent or inconsistent with physical reality. For example, one U.N. development plan set economic growth goals that were inconsistent with its population projections.

In short, the modelers generally agree that the world system is likely to undergo accelerated change and that, despite the occasional good news, a continuation of current trends and policies will ultimately lead to change for the worse. They agree that changes for the better are possible, although they disagree sharply on what those changes should be and which policies might bring them about. Finally, the modelers generally agree about the fundamental issues on which analysis and monitoring should focus and actions be taken. These include population growth, food supplies, resource shortages, and environmental losses.

Global trends in population, resources, and environment

At this point I would like to address several specific global trends that have been addressed in OTA reports.

Population.—After many thousands of years of relative stability—that is, a balance between birth rates and death rates—the world's population has grown dramatically over the past century or so. Although population growth rates are beginning to decline, some of the poorest nations still have very high rates of growth, with population doubling times as short as 18 years. By contrast, population growth in industrialized countries has almost stabilized over the past 30 years. This difference in growth rates between rich and poor nations could lead to considerable tension in the future.

Technology is both a cause of and a potential solution to this trend, but any solution must also involve social change. Improved health care and sanitation have cut death rates quickly, but technology affects birth rates more slowly because they are more closely tied to long-standing cultural values and practices. Thus, while the trends in world population are changing rapidly when measured in terms of social and cultural change, these trends are *very* different around the world. More than 90 percent of the global population growth between now and 2000 will come from people born in third world countries, where resources such as soil quality severely constrain any comparable growth in food production. If people had easy access to both present technologies and improved technologies, the total population in 2000 could be closer to the lower estimate of 5.9 billion than the higher estimate of 6.5 billion. The difference is roughly equal to the current population of Europe or Africa.

The task of providing necessities of life—much less the amenities—to these additional people will tax the resources of LDC's, which are already stretched thin. One can be optimistic about this situation only if one makes the unlikely assumption of a major and sustained contribution from the wealthiest nations. It is heartening to note that most developing nations now recognize that it is in their self-interest to lower population growth rates and now favor progress to that end. At the same time, the record of actual implementation of these programs is quite mixed: growth rates are markedly lower in China and other Asian nations, for example, but they remain high in the Arab states and in parts of the Caribbean, Central America, Sub-Saharan Africa, and elsewhere.

Resources.—The earth's crust is richly endowed with concentrations of "nonrenewable" energy and mineral resources. However, these resources are unevenly distributed, resulting in a basis for interdependence among nations. The richest concentrations of many of these resources (e.g. oil, metals) are being depleted rapidly, but the apparent loss is essentially offset by improved technology in exploration and production. That progress, however, may be confounded by rising energy costs. Advancing technology also provides manifold opportunities to substitute more common materials for less common ones, and to use less materials in providing various goods and services.

The earth's concentrations of "renewable" resources, such as hardwood forests, fertile grasslands, and well-watered farmlands, are also distributed unevenly. As a result, they too provide a basis for the interdependence of nations. Although these resources are potentially renewable, their renewability can be destroyed where they are mismanaged or overstressed.

These points mean that "resources" should not be thought of strictly in terms of ore deposits or acres of land, but increasingly as reflections of the state of technology and of wise management. Given this basically good news—that the availability of "resources" is subject to human influence—we must add some caveats. First of all, high technology, complex economies, and conservative management of resources are more characteristic of some countries than others. Second, some resources (e.g. the Ogallala aquifer in the Midwestern United States) are "substitutable" only with massive capital investments, and new capi-

tal is increasingly expensive these days. The widespread evidence of a decline in the natural productivity of farmland, whether by erosion or exhaustion of natural fertility, is articularly alarming.

Food.—Despite the improved yields and increased overall production of the last 20 years, several global models indicate that per capita food production will decline catastrophically about one generation into the next century. Population, in other words, may be outstripping food supply. This is because agriculture has become increasingly dependent on non-renewable resources for which other sectors of the world economy will be competing. The failures of the Green Revolution in the LDCs—due largely to rapid, unanticipated increases in the cost of fuel, fertilizer, and pesticide—have demonstrated that agricultural technologies cannot be developed in isolation from other sectors.

New technologies like bioengineering and sustainable biological farming systems hold considerable promise for meeting these challenges, but OTA has found that the potential for such technologies is being eroded by the accelerated extinction of plant and animal species. This problem is particularly acute where growing populations exert pressure on natural habitats, and habitat loss is compounded where the cultivation of marginal lands has led to soil erosion and reduced fertility.

Soil itself is an example of a potentially renewable resource that is having its renewability destroyed by the misuse of certain technologies. OTA's assessment of The Impact of Technology on the Productivity of U.S. Croplands and Rangelands indicates that soil erosion rates far exceed the rate of soil formation in the United States. The data suggest that the situation is considerably worse in the Third World, where population pressures are greater and local resources fewer. Mismanagement of such resources by the LDCs will make them increasingly dependent on food supplies from developed nations, but the developed nations face similar production constraints. Overuse of surface waters and groundwater in the arid and semi-arid regions of the United States may ultimately constrain our own agricultural production, with potentially serious consequences for world hunger and the U.S. balance of trade.

Energy.—The Limits to Growth is sometimes credited with having "predicted" the Arab oil embargo and resulting energy crisis of the 1970's, but in fact many of its direct projections have already proven inaccurate. It and other early global modeling work on energy trends simply projected historical growth in energy demand into the future, and assumed that GNP and energy use would continue to march in lockstep. This assumption, however, failed to take a number of important factors into account.

First of all, the price elasticity response—the degree to which the use of energy depends on its price—has proven to be considerably larger than expected. Secondly, the world economy has been able to provide attractive substitutes for energy through the application of technology. In addition, we have been able to bring demand growth down through improved end-use efficiency, a willingness to simply use less energy (as in lowered thermostats), and shifts away from energy-intensive industrial products and processes. Despite substantial economic growth, for example, energy demand growth in OECD countries has been less than one percent per year since 1973, compared to 5.2 percent per year from 1960 to 1973.

At the start of the 1980's, therefore, we see a global energy future that is not without complications but, in the industrialized world at least with several hopeful trends:

Drastically reduced projections of the use of energy in general and petroleum in particular (a recent OTA study projects oil supplies in the non-communist world in 2000 ranging from 40 to 62 million barrels per day, compared to 52 million barrels per day in 1979);

Increased diversification of both demand and supply choices for energy, as well as greater attention to end-use matching and other improvements in utilization; and

Particular interest in electrification and a new optimism about natural gas reserves, due in part to improved exploration and production technologies.

Water resources.—A great deal of water-resource modeling has been done on the local and regional level, especially for the industrialized nations, but very little modeling work has been done on global water supplies. What little we do know suggests that the prospects are poor, if not appalling, for many areas of the world by the year 2000. The per capita water availability projections in the Global 2000 suggest that, by the end of the century, water shortages will be more frequent and severe than those experienced today, with the greatest pressure in

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those countries with low per capita water availability and high population growth—especially in parts of Africa, South Asia, the Middle East, and Latin America. Population growth alone will at least double the demand for potable water in many countries by 2000, and water could be as major a problem in the 1980's as energy was in the 1970's.

Even these dismal projections are probably optimistic. The water projections in the Global 2000 Report assume that all of the runoff from rivers and streams will be captured for use. A more realistic estimate based on where and when the water is available relative to its desired use, would be only 35 percent of the total runoff globally.

Moreover, the Global 2000 projections of per capita water availability in the year 2000 explicitly do not consider how much of the available water will be of sufficiently good quality for its intended use. It is estimated that one-sixth of all fresh water resources are currently used to dilute sewage (about 20 percent of the world's population was served by sewers in 1970), and that—because of increases in population and the growing percentage of the population served by sewers—the volume of sewage-related discharge to streams may increase by as much as 5 to 15 times by 2000. And even this estimate does not take into account industrial and agricultural water pollution, which are certain to increase from development and population growth in many parts of the world unless specific preventative actions are taken. Clearly there is a need to develop and disseminate new technologies for treating, recycling, and conserving water.

Environmental conditions.—We have entered an era in which we can no longer expect the footprints of human activity to be washed away by natural environmental forces. This is due to both the extent and concentration of human activity. The explosion of human population is accelerating the conversion of forests into firewood and farms. The implosion of people and industry into large urban concentrations has overloaded local environments. Innovative technology is providing ways to reduce environmental damage, but progress is very mixed, especially when economic growth falters.

As premium mineral and energy resources are depleted, and as human population expands, it will be increasingly difficult to avoid further environmental losses. Our best hope for maintaining environmental resources is to succeed well enough in advancing technology and stabilizing population that environmental conditions can be improved.

Economic growth.—Growth for some nations, like the United States and the Soviet Union, will continue to be a mixture of the consumption and export of both natural resources and the products of technology. The trend will ultimately be toward the latter and, as a result, human ingenuity will be more and more our wellspring of hope for the future. Other nations like Saudi Arabia that are more completely dependent on the export of natural resources face the same challenge but must change more quickly. Still others, like Japan, already depend almost completely upon human ingenuity. Finally there are some countries who have less and less to offer by way of natural resources, who have little or no basis for participating competitively in international markets, and who therefore can only offer the world cheap labor and surplus populations. Compared to their plight—that of rising expectations and shrinking opportunities—the problems we face in the United States today seem to pale.

Global models and Government foresight

One important implication of all this information is the need for effective Government foresight—an improved ability to address long-range issues by anticipating future developments, formulating policies and programs that ameliorate emerging problems and exploit potential opportunities, and evaluating the effectiveness and impacts of these actions and investments. To do this we need three things. First of all, we need accurate and adequate data on the relevant conditions and regions. Secondly, we need an analytic capability—experts in the relevant disciplines and relevant agencies—with which to collect, interpret, and apply this data. And thirdly, we need the analytic tools—the technologies, if you will—that will enable experts to organize and analyze the data and present the results in ways that are useful to policymakers and planners.

A variety of models—global, national, and sectoral—already in use throughout the U.S. Government in a wide range of forecasting applications. The Joint Chiefs of Staff, for example, are developing a version of the World Integrated Model (WIM) for use in their Joint Long-Range Strategic Appraisal. The same model has been used by both the Department of Agriculture and the Bureau of

Mines, in combination with other tools. Numerous other Federal agencies routinely use regional or sectoral models in carrying out their long-range analysis and planning functions, including the Central Intelligence Agency and Department of Energy, as well as the Bureau of the Census and Environmental Protection Agency. Turning to the agencies under this Committee's jurisdiction, the Agency for International Development has used several models of population or resources on a nation-by-nation basis, but the modeling capability of the Department of State is relatively undeveloped. And no Federal agency is currently responsible for developing a consistent set of long-term economic growth projections for all the world's nations—those in Global 2000 were produced by the World Bank.

The question is not whether a Government modeling capability should exist—it already does, and it has proven itself increasingly useful. An expanded and better cordinated use of modeling could offer the Government an opportunity to improve its existing foresight capability—its ability to effectively address long-range issues by anticipating future developments, and then formulating policies and programs that will minimize potential problems and exploit potential opportunities. Although models cannot generate predictions of what will happen in the future, they can be used to produce conditional forecasts of what is likely to happen given certain specific assumptions about trends, policies, and events. This could allow models to become an effective aid to policymaking in four specific areas:

Assessing the future impacts of current trends and existing policies;

Monitoring the national and international situation for early signs of potential problems or opportunities;

Comparing broad alternative policies and courses of action for achieving national goals, avoiding potential problems, or exploiting potential opportunities; and

Providing a framework for ensuring consistency between assumptions and outcomes, between short- and long-term analyses, and across agency jurisdictions.

Although models in general are subject to a number of technical constraints, several assessments of the Government's modeling capability have concluded that institutional barriers impose as many constraints on their usefulness as do technical limitations. Frequently cited institutional barriers include the following:

Lack of consistent support and funding for data-gathering and model-improvement activities;

Poor communication between modelers and potential model users, resulting in models that are unresponsive to the specific information needs of policymakers;

Narrow specialization of interests and responsibilities, complicated by inadequate mechanisms for transferring data and resolving problems between agencies;

Lack of understanding, confidence, or support for modeling among top-level policymakers, resulting in a failure to integrate forecasting and policymaking activities; and

Lack of interest in long-term global issues on the part of Federal agencies, Congress, and the general public.

Proposals for improving the Government's modeling capability usually stress the need for a coordinated strategy involving complementary efforts at all levels. The proposed initiatives generally reflect four fundamental priorities:

Correct existing deficiencies.—Relevant agencies might create internal advisory committees to: (1) prepare an inventory of existing models, their uses, their deficiencies, and any planned modifications; (2) survey current or potential applications by analysts and policymakers, with particular attention to their specific information needs; (3) evaluate existing data bases to determine data needs and possible ways of gathering data that are scarce; and (4) improve communication between policymakers and modelers in order to increase the relevance and responsiveness of forecasts.

Coordinate existing capabilities and activities.—Some form of interagency mechanism might be established in order to: (1) identify areas of compatibility and sources of inconsistency among models; (2) promote communication and technical cooperation among agencies; (3) develop consistent standards and protocols for the reliability, validation, and documentation of both models and data; (4) provide a clearinghouse for easier access, exchange, and integration of other agencies' data assumptions, and projections; and (5) resolve problems among agencies through negotiation or arbitration.

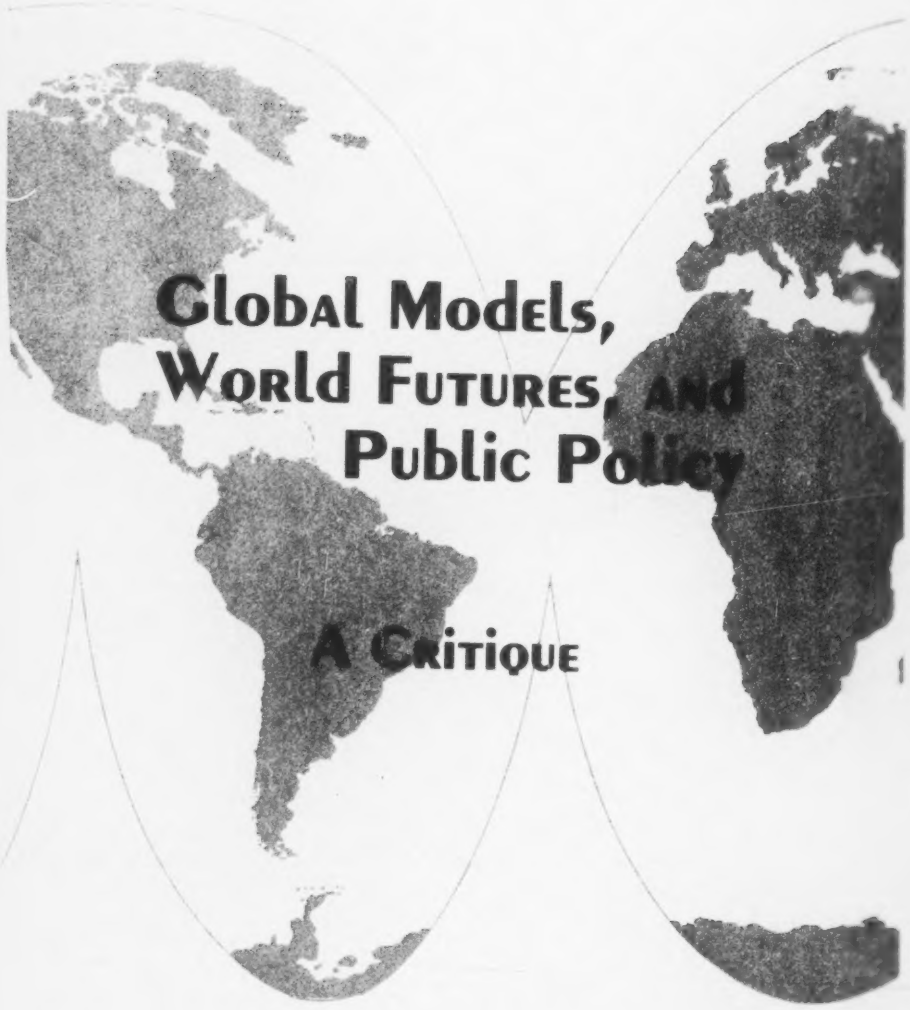
Support technical improvements in the Government's capability and the state of the art.—A group might be established within the Federal establishment responsible for long-range analysis and the coordination of specialized agency studies

examining global issues. The group would need to have the freedom to pursue any problem that seems likely to have a significant impact on the world economy of human suffering during the next few decades. Its goal should be largely one of identifying problems early enough to motivate a search for practical solutions. The group's specific functions might also include the following: (1) encourage impartial, third-party validation and assessment of existing models; (2) support nongovernmental research on global models and establish a "global modeling forum" (analogous to the Energy Modeling Forum at Stanford University) at which modelers could exchange ideas and critique on another's work; (3) enlist the talents and participation of the private sector in Government foresight activities; and (4) assess and stay in contact with modeling work done outside the United States.

Link foresight with policymaking.—The foresight capabilities of the legislative research agencies could be coordinated and upgraded and/or a new unit could be created in the Executive Office of the President. The functions of a new Executive Branch unit might be to: (1) supervise and/or coordinate the strategies outlined above; (2) provide the President and other top-level decisionmakers with thorough analyses and a broad range of policy options on global issues; (3) evaluate the long-term effects of agency goals and budget items on global trends and U.S. strategic interests, for consideration by the Office of Management and Budget and Congress in the budgetary process; (4) prepare a "policy statement on the future" to be delivered bi-annually by the President to the Congress; (5) issue periodic reports on specific global studies of long-range trends and problems at regular intervals; and (6) in conjunction with the Department of State, encourage foreign national assessments of long-range issues and support the data-gathering, analytic, and problem-solving activities of the United Nations, international financial institutions, and nongovernmental organizations.

Closing thoughts

The traditional approach to long-range planning is "we'll muddle through somehow," but there is good reason to believe that time has run out on this venerable attitude. The dilemmas I have outlined are unprecedented in scale. Unlike the past, there will be no easy escape by finding areas with new natural resources. We are beginning to approach the global limits in oil, gas, fresh water, and arable land. The problems are also emerging at an unprecedented rate. The mathematics of accelerating growth are catching up with us. Many of the most sensible solutions will take years or decades to have an effect, and in some areas we don't have the luxury of waiting that long. It simply may not be possible to solve many global problems with bandaids once the hemorrhages have actually begun. Muddling through may work one more time—but I for one would not like to take the chance.



Global Models, World Futures, and Public Policy

A Critique

CONGRESS OF THE UNITED STATES
Office of Technology Assessment
Washington, D.C. 20510

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GLOBAL MODELS, WORLD FUTURES, AND PUBLIC POLICY

A CRITIQUE

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CONGRESS OF THE UNITED STATES
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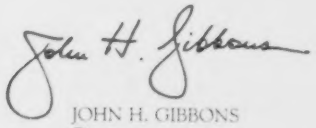
Foreword

A number of long-range forecasts of international demographic and economic trends have been published over the last decade, many of them based on the findings of global models—computerized mathematical simulations of the world's physical, economic, and political systems. This report responds to a request by the Technology Assessment Board for an evaluation of the methodologies, findings, and implications of Global 2000 and other global modeling studies.

Computerized models are a useful way of handling a large amount of data at once and of keeping assumptions and calculations self-consistent. In this connection, our study not only reviewed the findings and recommendations of five major global modeling studies, but also examined the underlying assumptions and data bases on which those results are based.

The purpose of this report is neither to confirm nor to disprove the sometimes rosy but more often dire predictions derived from global modeling studies, but rather to examine the present use and potential usefulness of this rapidly developing technology as a powerful tool for long-range strategic analysis and policy development. OTA found significant and growing use of models by a variety of Federal agencies. In addressing the modeling capability of the Government, the report focuses not on whether models should be used—they already are, and have proven themselves valuable over a period of years—but rather on how to improve this capability and make its projections more useful to analysts, planners, decisionmakers, and the broader public.

We were greatly aided by the contributions of a number of contractors and by the guidance and expertise of the many individuals who generously provided information and review comments. Their assistance is greatly appreciated.



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Acknowledgments

OTA wishes to thank the following people who took time to provide information or review part or all of this study.

David Barnhizer
World Wildlife Fund
Barbara Baum
U.S. Department of State
Anne Cheatham
Congressional Clearinghouse on the Future
Cheryl Christiansen
U.S. Department of Agriculture
Bill Davis
OTA Materials Program
Georges Fauriol
Center for Strategic and International Studies
Georgetown University
Katherine Gilman
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U.S. Environmental Protection Agency
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Command and Control Technical Center
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CHAPTER 1

Overview

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CHAPTER 1

Overview

The last 15 years have witnessed a growing international effort to increase understanding and broaden public awareness of the conditions, problems, and opportunities that are likely to confront the world through the end of this century and into the more distant future. This ongoing "futures debate" has been stimulated in part by the publication of a series of long-range forecasts of global trends in population growth, resource availability, economic development, and environmental conditions. Many of these forecasts have been based on the findings of "global models"—computerized mathematical simulations of the world's physical, economic, and political systems. As tools of strategic analysis, these models have been used to study the interactions and future implications of past events and current trends. As tools of policy formulation, global models have been used to evaluate or promote alternative actions and programs that might bring about different or more favorable world futures.

This report surveys the assumptions, findings, and recommendations of five major global modeling studies (see table 1). It also considers the use of global models within the U.S. Government, such as the World Integrated Model (WIM) that is being used by the U.S. Joint Chiefs of Staff (see pp. 23-24). In addition, the report presents strategies that have been suggested for improving the quality and relevance of the Government's modeling capability. Of great interest in this connection is the newly created White House "national indicators system" (see p. 65). The appendixes provide detailed comparative analyses of the models' projections of population, agriculture, and energy trends.

Table 1.—Summary Description of the Five Global Modeling Studies Discussed in This Report

Model	Date	Historical base period	Projection time horizon	Geographical regions	Alternative scenarios[a]
World 3	1972	1900-1970	2100	1 (global)	11
World Integrated Model (WIM)	1974	1950-1975	2025	10 (later 14)	17
Latin American World Model (LAWM)	1976	1960-1970	2060	4 (later 15)	7
United Nations Input-Output World Model (UNIOWM)	1977	1970[b]	2000	15 (3 blocs)	13
Global 2000	1980	Not consistent	2000	5 to 28 (Not consistent)	12

[a]Number of computer runs, sensitivity tests, or policy scenarios examined by Office of Technology Assessment in the text of appendixes of this report.
[b]System structure and behavior in 1970 were verified through comparison with cross-sectional data dating back to 1955 or 1960.

SOURCE: Office of Technology Assessment.

Findings of the Global Models

Global modeling studies have varied widely in their purposes, techniques, findings, and prescriptions. The results of some studies have been guardedly optimistic, while others have been highly pessimistic. Their specific quantitative results have been different because they have made different assumptions and have focused in different ways on different parts of the global system. Nevertheless, they have generally identified the same problems and seem to have arrived at roughly similar qualitative conclusions about the present state of the world and its plausible futures:

- Population and physical capital cannot grow indefinitely on a finite planet without eventually causing widespread hunger and resource scarcities. However, there is no physical or

technical reason why basic human needs could not be supplied to all the world's people, now and for the foreseeable future. These needs are not now being met because of unequal distribution of resources and consumption—not overall physical scarcities. The absence of physical limits, however, does not necessarily imply the existence of a practical solution.

- The continuation of current trends would result in growing environmental, economic, and political difficulties. As a result, "business as usual" is not a palatable future course. Technological progress is expected (and in fact essential), but no set of purely technical changes tested in the models was sufficient in itself to bring about a completely satisfactory outcome. The models suggest that social, economic, and political changes will also be necessary.
- Over the next two or three decades, the world's socioeconomic system will be in a period of transition to a state that will be significantly different from the present. However, the shape of this future state is not predetermined—it is a function of decisions and changes being made now.
- Because of the complexity, momentum, and interdependency inherent in the world's physical and socioeconomic systems, the full long-term effects of a given action are almost impossible to predict with precision or certainty. However, actions taken soon are likely to be more effective and less costly than the same set of actions taken later, and cooperative long-term approaches are likely to be more beneficial for all parties than competitive short-term approaches.
- Many existing plans and agreements—particularly complex, long-term international development programs—are based on assumptions about the world that are either mutually inconsistent or inconsistent with physical reality.
- Pollution and resource availability may or may not be problems on a global scale, but there is general agreement that regional problems of global concern—such as food shortages in South Asia and perhaps Sub-Saharan Africa—are far more likely than a global collapse.

In some cases individual global models have been used to support more dramatic conclusions and more specific prescriptions than these, but it would be a mistake to confuse global modeling *as a method of analysis* with any particular prediction or recommendation. As a tool of analysis, global modeling is in itself neutral, although like any complex tool a given model can be designed or used inappropriately. For instance, most global models contain little or no representation of geopolitics; it would thus be inappropriate to use them to predict short-term events that may in fact be more strongly affected by nonquantifiable political variables. Similarly, the findings that come out of a model will also depend on the data and assumptions that go into it, the purposes to which it is put, and the way it is interpreted. As a result, global modeling can be a useful technique in long-range analysis, but it should not be—nor is it likely to become—the sole, or even the principal, basis for decisionmaking.

Global Modeling and Government Foresight

Global modeling is used by a variety of organizations and is by no means the exclusive preserve of environmentalists or those who advocate a "new international economic order." A growing number of large domestic and multinational corporations routinely employ the projections of private economic modeling services in their corporate planning. Several foreign governments and international organizations support ongoing global modeling programs, and a variety of models—global and otherwise—are also in use throughout the U.S. Government in a wide range of forecasting applications. The Joint Chiefs of Staff, for example, are developing a version of WIM for use in their joint long-range strategic appraisal, and both the Department of Agriculture and Bureau of

Mines have used WIM as well as other models. The Global 2000 Study found that numerous Federal agencies (including the Central Intelligence Agency and Department of Energy, as well as the Agency for International Development, Bureau of the Census, and Environmental Protection Agency) routinely use regional or sectoral models in carrying out their long-range analysis and planning functions. Similarly, the Members and committees of Congress have access to long-term econometric models maintained by the Congressional Budget Office (as well as the findings of models maintained by the executive agencies) for use in their oversight, assessment, and legislative functions. This Government modeling capability exists because it is necessary, and it has shown itself to be useful over the years.

The expanded and better coordinated use of global models could offer the U.S. Government an opportunity to improve its existing foresight capability. "Foresight" relates to the ability to effectively address long-range issues by first anticipating future developments, and then formulating policies and programs that will minimize potential problems or exploit potential opportunities. Although global models cannot generate precise, detailed predictions of what *will* happen in the future, they can be used to produce conditional forecasts of what is *likely* to happen or the *probability* of different outcomes, given certain specific assumptions about trends, policies, and events. They can also be used to test the consistency of assumptions and predicted outcomes for different policy options. In addition, the models can generate order-of-magnitude estimates of many demographic, economic, and resource factors at the global, regional, and national levels.

This level of forecast accuracy and detail can be useful for a wide range of applications in long-range assessment and policy-development activities. Deficiencies do exist in the Government's current capability, but if these deficiencies are corrected global models could become a more effective input to policymaking in four specific areas:

- assessing the future impacts of current trends and existing policies;
- monitoring the national and international situation to identify early signs of potential problems or opportunities;
- formulating and testing a wide range of alternative policies and courses of action for achieving national goals, avoiding potential problems, and exploiting potential opportunities; and
- providing a framework to ensure consistency between short- and long-term analyses and across agency jurisdictions.

Strengths and Weaknesses of Global Models

Global models offer a number of methodological advantages over traditional techniques of long-range analysis and policy development:

- *Longer time horizon.*—Traditional methods are used primarily for annual or short-term forecasts, whereas global models typically have horizons of 20 years or more. This allows global models to assess long-term effects and cumulative changes that might not otherwise be anticipated.
- *Comprehensiveness.*—The computer can contain far more information about a system or process than any single mental or verbal model, and it can keep track of far more interrelations and variables at the same time. Global models can therefore enable the analyst to utilize substantially more information, and do so more meaningfully (e.g., with regional disaggregation) than could otherwise be done.
- *Rigor and accessibility.*—Modeling requires explicit, precise, and complete statements of objectives, assumptions, and procedures. These must be written out before they can be run on the computer, and this makes it easier for all sides to examine them and point out omissions and inconsistencies. Open communication about the system and the model can lead to revisions and refinements even before analysis begins, and it can also contribute to the dialog through which clear-cut goals are established.

- *Logic.*—The computer can draw logically correct and mathematically error-free conclusions from an extremely complicated set of assumptions and data. This can lead to insights into unexpected or counterintuitive system behavior, reveal areas in which further research is needed, and expose assumptions and objectives that are inconsistent, contradictory, or physically impossible.
- *Flexibility.*—It is possible to tailor global models to fit particular problems or regions. By changing the magnitude of specific variables and relations, global models can also be used to test a wide range of assumptions and policy alternatives. This can make the global model a valuable tool for policy formulation, as well as a device with which planners and policymakers alike can sharpen their analytic skills and improve their intuitive "feel" for the probable behavior of global systems.

Global models are, however, subject to a number of limitations that can constrain their accuracy, reliability, and usefulness:

- *Methodological constraints.*—The essence of modeling is a simplification that improves understanding, but this means that a limited set of discrete factors and relations are used to describe the complexity and ambiguity of the real world. There is little agreement, however, on the proper level of complexity or integration. Similarly, there are no generally accepted tests of model realism, making quality control and third-party validation important considerations.
- *Theoretical constraints.*—Current understanding of some causal relationships is far from adequate, particularly for environmental and sociopolitical processes, and this too can lead to inaccurate or invalid assumptions. As a result, the theoretical biases of the modelers—or the specific needs and assumptions of model users—can sometimes lead to oversimplification or distortion.
- *Data constraints.*—In many areas there is a lack of adequate, reliable, and consistent data. This, too, can be a source of forecast error, as well as a constraint on the issues or regions to which global models can be reliably applied.

Because of these limitations, it is vital to evaluate the assumptions and uncertainties underlying the forecasts, if the results are to be understood and used by policymakers.

Institutional Barriers

Several assessments of the Government's modeling capability have concluded that the institutional context in which models are currently used is as much of a constraint on their usefulness as the above technical limitations. Frequently cited institutional barriers include the following:

- poor communication between modelers and potential model users, resulting in projections that are unresponsive to the information needs of policymakers;
- narrow specialization of interests and responsibilities, at the expense of interactions among sectors and cooperation among agencies, complicated by inadequate mechanisms for transferring data and resolving problems between agencies;
- lack of understanding, confidence, or support for modeling among top-level policymakers, resulting in a failure to integrate forecasting and policymaking activities; and
- lack of interest in long-term global issues on the part of the Federal agencies, Congress, and the general public.

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Strengthening the Government's Modeling Capability

Proposals for improving the Government's modeling capabilities usually stress the need for a coordinated strategy involving complementary efforts at all levels. The proposed initiatives generally reflect four fundamental priorities:

- *Correct existing deficiencies.*—Relevant agencies might create internal advisory committees to: 1) prepare an inventory of existing models, their uses, their deficiencies, and any planned modifications; 2) conduct a survey of current or potential applications by analysts and policymakers, with particular attention to their specific information needs; 3) evaluate existing data bases to determine data needs and possible ways of gathering data that are scarce; and 4) improve communication between policymakers and modelers in order to increase the relevance and responsiveness of forecasts.
- *Coordinate existing capabilities and activities.*—Some form of interagency mechanism might be established in order to: 1) identify areas of compatibility and sources of inconsistency among models; 2) promote communication and technical cooperation among agencies; 3) develop consistent standards and protocols for the reliability, validation, and documentation of both models and data; 4) provide a clearinghouse for easier access, exchange, and integration of other agencies' data, assumptions, and projections; and 5) resolve problems among agencies through negotiation or arbitration.
- *Support technical improvements in the Government's capability and the state of the art.*—An independent or "quasi-public" institute might be created to promote research on global modeling and futures research. Its specific functions might be to: 1) encourage impartial, third-party validation and assessment of existing models; 2) support nongovernmental research on global models and establish a "global modeling forum" (analogous to the Energy Modeling Forum at Stanford University) at which modelers could exchange ideas and critique one another's work; 3) enlist the talents and participation of the private sector in Government foresight activities; and 4) assess modeling work done outside the United States and maintain communication with international organizations such as U.N. agencies and the International Institute of Applied Systems Analysis.
- *Link foresight with policymaking.*—To ensure that long-range global issues are routinely taken into consideration in the formulation and implementation of U.S. policy, Congress may wish to coordinate and upgrade the foresight capabilities of its legislative research agencies and/or authorize the creation of a new unit in the Executive Office of the President. The functions of this new unit might be to: 1) supervise and/or coordinate the strategies outlined above; 2) provide the President and other top-level decisionmakers with thorough analyses and a broad range of policy options on global issues; 3) evaluate the long-term effects of agency goals and budget items on global trends and U.S. strategic interests, for consideration by the Office of Management and Budget and Congress in the budgetary process; 4) prepare a "policy statement on the future" to be delivered by the President; 5) issue periodic reports on specific global issues; 6) conduct comprehensive, integrated studies of long-range trends and problems at regular intervals; and 7) in conjunction with the Department of State, encourage foreign national assessments of long-range issues and support the data-gathering, analytic, and problem-solving activities of the United Nations, international financial institutions, and nongovernmental organizations.

Conclusions

1. Global modeling represents an important analytic tool for exploring alternative world futures and for testing the feasibility and long-term effects of alternative policy actions.
2. The current state of the art in global modeling offers the U.S. Government a significant opportunity to improve its foresight capability, if the models are used judiciously and in combination with other techniques and inputs to strategic analysis and policy development.
3. If models are to be used properly within their present limitations, it is critical to: 1) determine and state explicitly the purposes, assumptions, and theoretical biases of the model; 2) ascertain the extent of uncertainty in a particular projection and its sensitivity to changes in the underlying assumptions; and 3) differentiate between descriptive forecasts and those that are prescriptive or normative.
4. Improvements in socioeconomic theory, modeling methodology, and data-gathering technologies could substantially improve the usefulness of the projections generated by global models.
5. Existing deficiencies in the Government's modeling capability are institutional as well as technical in nature, and any effort to correct these deficiencies will require better coordination among Federal agencies and increased attention to the information needs of policymakers and decisionmakers.

CHAPTER 2

Major Global Modeling Studies

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CHAPTER 2

Major Global Modeling Studies

Introduction

Forecasts and Forecasting

Formal forecasting, which appeared in the early 20th century, is based on the rigorous application of empirical inquiry and statistical analysis to the prediction of socioeconomic change. It insists on careful monitoring, a firm data base, and the judicious use of trend extrapolation, while rejecting unfounded optimism and utopianism as "wishful thinking." The first use of formal forecasting by the U.S. Government came in 1929, when President Hoover created a Presidential Research Committee on Social Trends, and its techniques and findings became linked with comprehensive planning and decisionmaking during the New Deal. Further theoretical improvements and practical applications have emerged since World War II through developments in econometrics, general systems theory, cybernetics, operations research, and input-output analysis.[1]

For strategic analysis and policymaking purposes, three general types of forecasts can be distinguished, based on their approach to foreseeing the future:[2]

- **unconditional forecasts,** which determine that certain events or trends will, in all probability, occur in the future (these forecasts might properly be called "predictions");
- **conditional or probabilistic forecasts,** which determine that certain events or trends are more or less likely to occur in the future, given certain limiting assumptions concerning present and future conditions and policy actions (and that, given a different set of assumptions, different events or trends are more or less likely to occur); and
- **exploratory forecasts,** which examine a wider range of policies and trends in an open-ended exploration of possible future developments, with less emphasis on the plausibility of assumptions or scenarios.

To these three types of descriptive forecasts, which attempt to project what will or might happen in the future, a fourth could be added:

- **prescriptive or normative forecasts,** which identify events or trends that should (or should not) happen and determine the policies and conditions that will promote the desired outcome.

Models and Modeling

A model is a simplified or generalized representation of something else—an object, process, or system. The model need not resemble the original and can in fact take many forms, depending on the purpose it is to serve: as an aid to *memory*, a small two-dimensional photograph can remind us of a large three-dimensional person or place we have seen; as an aid to *discovery*, a 3-lb model airplane can be tested in a wind tunnel to predict the performance of a 30-ton airliner built on the same design; and as an aid to *explanation*, a set of gravitational equations can be used to elucidate the intricate motion of planets orbiting a sun.

The model need not depict every detail of the thing it represents. A good model reduces the complexity of the original by eliminating elements and relations that are irrelevant to the purpose at hand, retaining only the characteristics that are needed for that purpose. Ingeniously simple models may be described as "elegant," but in the end *"a model can be made and judged only with respect to a clear purpose."*[3]

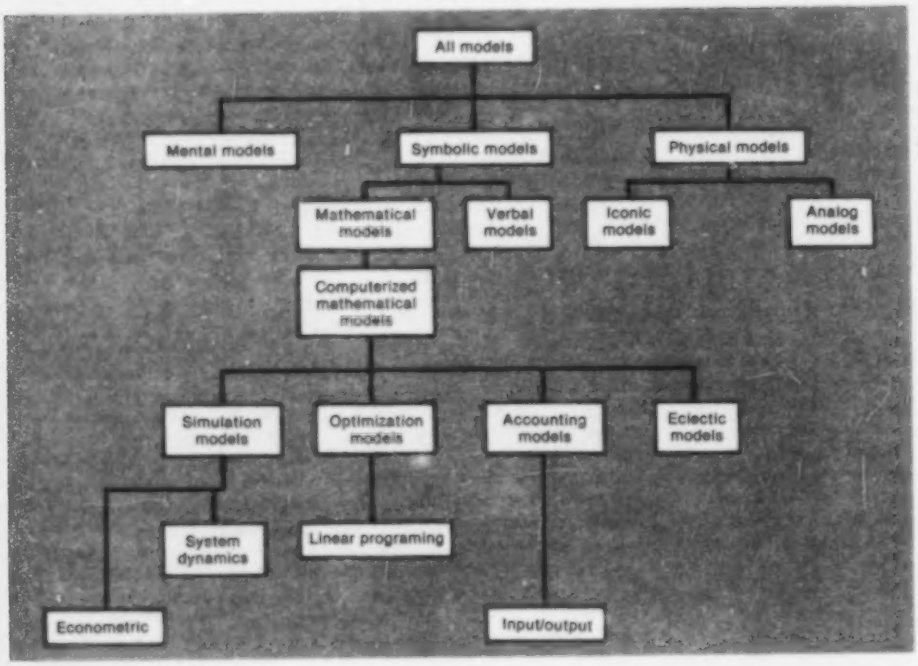
Models can be divided into three basic types: mental models, physical models, and symbolic models (see fig. 1). **Mental models** are the concep-

[1]Dennis L. Little, et al., *Long-Range Planning* (Washington, D.C.: U.S. Library of Congress Congressional Research Service, 1976), prepared for the Subcommittee on the Environment and the Atmosphere of the House Committee on Science and Technology, pp. 384-390.

[2]Arthur D. Little, Inc., *Long-Range Forecasting Models of Population, Natural Resources, and the Environment: Their Use in Foreign Policy Assessments at the National Level* (prepared for the U.S. Department of State, Nov. 1979), pp. II.2-3.

[3]Donella H. Meadows, John Richardson, and Gerhart Bruckmann (eds.), *Groping in the Dark: The First Decade of Global Modeling* (New York: Wiley, forthcoming), pp. 37-38; emphasis theirs.

Figure 1.—Types of Models



SOURCE: Arthur D. Little, Inc.

tual models people carry about in their heads and use to think about the world. They are flexible, adaptable, creative, and contain rich stores of information about such intangible factors as values and motivations. Some mental models are extremely subtle and elaborate, even elegant. But they can also be vague, shifting, unverbalized, and immune to objective criticism, and they are often based on dubious but strongly held assumptions. Judgmental and qualitative forecasts (including many unconditional forecasts) are often based on mental models.[4]

Physical models are created from tangible materials, and the process of embodying the model can usually make it both more explicit and more open to objective criticism. **Iconic or schematic models,** such as maps or diagrams, are physically similar to their originals, although they may not behave in the same manner. **Analog models,** such as wind tunnels, reproduce the behavior of their originals without necessarily resembling them in appearance.[5] Physical models can be a useful means of communicating, clarifying, and correcting mental models.

Symbolic models make use of some system or language of symbols to describe the relevant elements and relations of the object, process, or system they represent. **Verbal models,** such as *Das Kapital* or *Wealth and Poverty*, take the form of oral or written language. As a result, they can be more

[4] Ibid., pp. 20-21, 37-38, and Arthur D. Little, Inc., op. cit., p. II.6.

[5] Arthur D. Little, Inc., op. cit., p. II.6.

explicit and precise than mental models, but at the same time they are potentially diffuse, impressionistic, ambiguous, and rhetorical. **Mathematical models,** on the other hand, can represent the relevant elements and relations of a real object, process, or system in mathematical symbols and equations. This allows them to express complex operations concisely, precisely, and explicitly in a rigorous and consistent language. This in turn makes them more open to objective criticism and correction, but mathematical models remain susceptible to omissions, distortions, and misinterpretations like those that afflict mental and verbal models. They can be no more valid or reliable than the theoretical understanding on which they are based and the mathematical form in which they are expressed.

Computerized models are mathematical models that have been rewritten in a programing language that can be run on a computer. They can be used to investigate a process, system, or theory that is too large or too complicated to model adequately (or manipulate conveniently) in words or a few simple equations.[6] Such models can contain more elements (variables), more relations (equations), and far more empirical data than simpler models. The computer can keep track of all of these factors simultaneously, manipulate them very rapidly, and produce results that are free from computational error. However, human judgment is still required to determine what factors to include, how to represent them, what data to use, and how to interpret the numerical findings. Consequently, the results that come out of the computer are only as reliable as the general assumptions, structural decisions, and data that go into it, and even the best results are subject to biased or mistaken interpretations.

Global models are simply computerized mathematical models whose purpose is to investigate systems, theories, and issues of a global scale and complexity, usually with a relatively long time horizon:

> Global modeling is distinguishable from other types of modeling of social systems only by the questions it asks. Its methods, strengths, and weaknesses are identical to those of all policy-oriented computer models. It draws from the same base of theory and data. Therefore, if there are any distinct properties of global modeling, they follow directly from the characteristics of global problems.[7]

The following survey will therefore focus not only on the modeling techniques that have been used and the findings that have resulted, but also on the global problems that have been addressed in the models and the purposes to which their findings have been put.

[6] Meadows, Richardson, and Bruckmann, op. cit., p. 20.

[7] Ibid., p. 45.

The Trend Away From Technological Optimism

Until about 1970, most long-range forecasts were characterized by generalized optimism about the benefits of continued economic growth and confidence in the ability of technology to overcome any barriers. The most influential of the forecasts was *The Year 2000,* by Herman Kahn and Anthony Wiener of the Hudson Institute, which offered a set of alternative "scenarios" as a "framework for speculation" on the future. Its central finding was "that economic trends will proceed more or less smoothly through the next thirty years and beyond," and that "we are entering a period of general political and economic stability at least so far as the frontiers and economies of most of the old nations are concerned."[8] This "surprise-free" scenario was based on exponential extrapolations of postwar demographic and economic trends, but it was also influenced by the authors' underlying assumption of "continuity" in global affairs, particularly the increased rate of technological innovation, and by their confidence that society would be able to find "physically nonharmful methods of over-indulging."[9] Kahn and

[8] Herman Kahn and Anthony Wiener, *The Year 2000: A Framework for Speculation on the Next Thirty-three Years* (New York: Macmillan, 1967), pp. 116-128; emphasis added.

[9] Ibid., pp. 6, 122, 52.

Wiener do caution that "increasing discrepancies between rich and poor" could lead to resentment and instability, and that the "problems of development constitute a serious economic and moral concern."[10] Nevertheless, according to one critic, "they simply refuse to be overawed by the magnitude of the problems posed."[11] Although sharply criticized in recent years, this view of the future has remained influential in both Government and corporate policy, as well as public opinion, in the United States.[12]

Since the late 1960's—and particularly since the 1973 oil embargo—a less optimistic view of the future has gained currency, a view characterized by increased concern for the feasibility and environmental consequences of unrestrained economic growth and by criticism of the social and political institutions that have supported such growth. This new mood, which has been characterized as "neo-Malthusian pessimism," was influenced in part by the projections of economist Joseph Spengler and by the popular success of several books by Anne and Paul Ehrlich, who argued that the world is already over-populated and overdeveloped in terms of its ecological resources.[13] By far the largest stimulus to public debate over these issues came from the activities of the Club of Rome (an international group of businessmen, academics, and civil servants) that was organized in 1968 by Italian management consultant Aurelio Peccei.

The Club of Rome's "Project on the Predicament of Mankind" focuses on the complex interacting socioeconomic problems that make up the so-called "world problematique:"[14]

- poverty in the midst of plenty;
- degradation of the environment;
- loss of faith in institutions;
- uncontrolled urban spread;
- insecurity of employment;
- alienation of youth;
- rejection of traditional values; and
- inflation and other monetary and economic disruptions.

The predicament of mankind, according to the Club, is to be able to perceive this problematique but to be unable to understand its origins or operation and, therefore, unable to respond to it effectively.

The Club's continuing program, consequently, has two objectives: 1) to gain a better understanding of the limits of the world system, the interaction of its dominant elements, and the constraints it puts on human numbers and activities;[15] and 2) to encourage appropriate sociopolitical reforms by bringing the world problematique to the attention of the general public and (more pointedly) the world's leaders and decisionmakers. The Club "hit on the idea of using a computer to advertise their cause," as one critic puts it, not only because "the field of Systems Dynamics had created a body of expertise uniquely suited to the research demands," but also because the resulting report might prove to be "a vehicle to move the hearts and minds of men out of their ingrained habits."[16] These dual purposes led to the first true global model, which also remains the best known and the most controversial.

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[10]Ibid., pp. 142, 164.

[11]Sam Cole, "The Global Futures Debate 1965-1976," in *World Futures: The Great Debate*, Christopher Freeman and Marie Jahoda (eds.) (New York: Universe Books, 1978), p. 23.

[12]M. Marien, "Herman Kahn's 'Things to Come,'" *Futurist*, February 1973, p. 7; cited by Cole, op. cit., p. 23.

[13]Cole, op. cit., p. 27; see also Joseph Spengler, "The Economist and the Population Question," *American Economic Review*, December 1966, and *Population Change, Modernization and Welfare* (Englewood Cliffs, N.J.: Prentice-Hall, 1974); see also Paul R. Ehrlich, *The Population Bomb* (New York: Ballantine Books, 1968), and Anne and Paul R. Ehrlich, *Population, Resources, Environment: Issues in Human Ecology* (San Francisco: Freeman, 1970).

[14]William Watts (President, Potomac Associates), "Foreword," in *The Limits to Growth*, by Dennis L. Meadows, et al. (New York: Universe Books, 1972), pp. 10-11.

[15]Aurelio Peccei, et al., "Commentary," in *The Limits to Growth*, p. 185.

[16]Cole, op. cit., pp. 28-29; and Watts, op. cit., p. 11.

World 3—The Limits to Growth

Origin and Purpose

In June 1970, when the Club of Rome was seeking a suitable methodology for their investigation of the global system, Jay Forrester of the Massachusetts Institute of Technology (MIT) invited the group to Cambridge for a demonstration of the capabilities of systems dynamics. Within 3 weeks he designed and documented a simple global model—World 1—as the basis for presentations and discussions at the end of July 1970. (A revised version, World 2, was the subject of Forrester's subsequent *World Dynamics* (1971).) Impressed, the Club obtained a $250,000 grant from the Volkswagen Foundation to fund Forrester's colleague Dennis Meadows and a team from MIT in developing a full-scale model—World 3—based on the systems dynamics approach. Under the auspices and direction of the Club of Rome, the MIT team produced both an elaborated model and a popularized presentation of it in less than 2 years—perhaps too quickly, in the view of one critic:

> The Club only relinquished control when the exercise had produced their desired product, as evidenced by the fact that client pressure drove the modelers to violate their scientific values by publishing *The Limits of Growth* before the technical documentation for World 3 was completed.[17]

Structure and Assumptions

The World 3 model describes the global system in terms of five interacting subsystems—population, natural resources, capital, agriculture, and pollution—which are averaged on a global basis. *Its most important conceptual contribution is the incorporation of "feedback" relations between these variables*; due to these relations, attempts to solve one problem may unintentionally exacerbate another. The model also introduced the concept of "carrying capacity"—the level of population and production that could be sustained indefinitely by the prevailing physical, political, and biological systems of the world—and posited four possible "behavior modes" that a growing population could exhibit with regard to this carrying capacity (see fig. 2). None of these behavior modes reflects the potential ability of technology to *expand* the carrying capacity, primarily because *the model assumes nonsubstitutibility between technology and resources.*

The purposes of the model, according to the authors, were "to determine which of [these] behavior modes . . . is most characteristic of the globe's population and material outputs under different conditions and to identify the future policies that may lead to a stable rather than an unstable behavior mode."[18] According to one critic, however, given the authors' "specific motivating concern with limits, the broad conclusions that emerged from the model are, perhaps, not surprising"—they assumed that limits exist and would eventually be reached; "[the] question was when and how."[19]

Findings of World 3

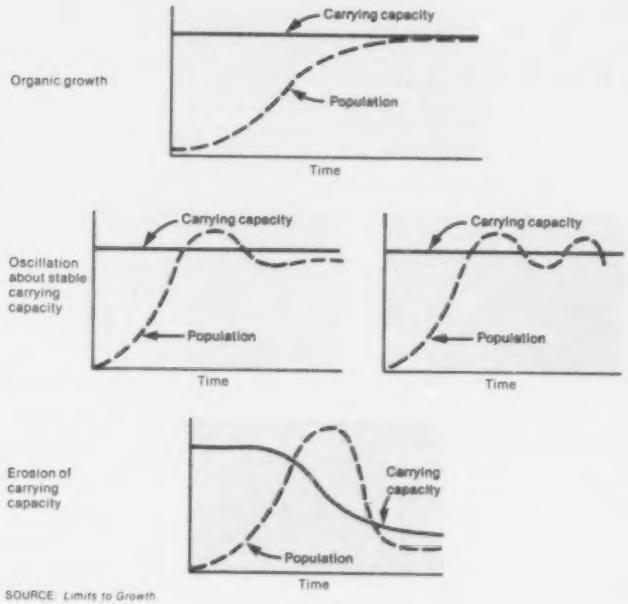
The standard or "reference run" of World 3, based on a continuation of the trends that have characterized the world system since 1900, results in the model output that has given *The Limits of Growth* its reputation for "gloom and doom" (see fig. 3). In this case the collapse of the system is caused by rapidly expanding population and in-

[17]Jennifer Robinson in Meadows, Richardson, and Bruckmann, op. cit., p. 408.

[18]Dennis L. Meadows, et al., *Dynamics of Growth in a Finite World* (Cambridge, Mass.: Wright-Allen, 1974), p. 8.

[19]Meadows, Richardson, and Bruckmann, op. cit., p. 61.

Figure 2.—Possible Global Behavior Modes



SOURCE: *Limits to Growth.*

dustrial output and a diminishing resource base. Essentially the same results are achieved in additional runs with increasingly optimistic assumptions about the five system variables:

- doubling the nonrenewable resource base;
- "unlimited" nuclear power and extensive recycling;
- strict and effective pollution control;
- doubling the average agricultural yield; and
- "perfectly effective" but voluntary birth control.

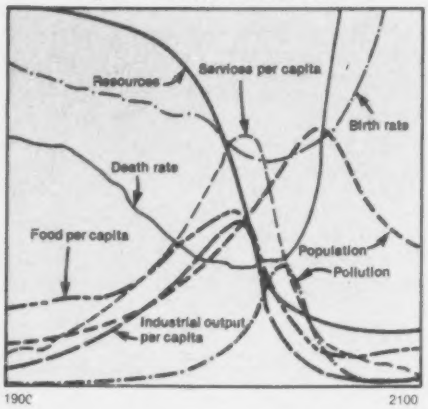
In some of the runs population and industrial production climb to higher levels before collapsing, but—according to this analysis—no single technological change can avert the final catastrophe, nor can any combination of them delay the collapse beyond the year 2100. In some runs the collapse is caused by a resource crisis, in others by a pollution crisis or a food crisis; but no matter what the assumptions, say the authors, "The basic behavior mode of the world system is exponential growth of population and capital, followed by collapse."[20]

In keeping with their second objective, the MIT team also used the World 3 model to identify conditions and policies that would avoid these problems and lead to a stable behavior mode like one of those in figure 2. Continuous growth was ruled out by the basic assumptions of the model; they were looking for an output that represented a "sustainable" world system that would avoid collapse and would also be "capable of satisfying the basic material requirements of all of its people."[21]

By working backward from the desired outcome to the conditions that would produce it, the authors were able to find a combination of "realistic" policy changes that, implemented simultaneously

[20]Meadows, et al., *The Limits to Growth*, p. 142.
[21]Ibid., p. 158.

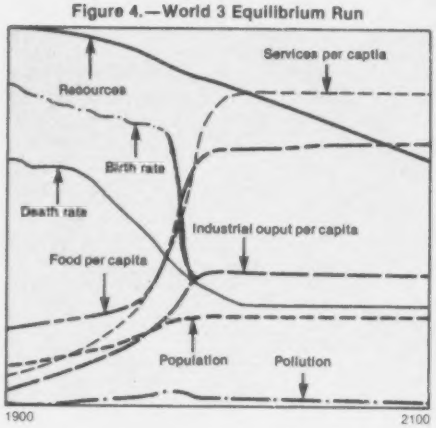
Figure 3.—World 3 Standard Run



The "standard" world model run assumes no major change in the physical, economic, or social relationships that have historically governed the development of the world system. All variables plotted here follow historical values from 1900 to 1970. Food, industrial output, and population grow exponentially until the rapidly diminishing resource base forces a slowdown in industrial growth. Because of natural delays in the system, both population and pollution continue to increase for some time after the peak of industrialization. Population growth is finally halted by a rise in the death rate due to decreased food and medical services.

SOURCE: *Limits to Growth*

Figure 4.—World 3 Equilibrium Run



Technological policies and growth-regulating policies produce an equilibrium state sustainable far into the future. Technological policies include resource recycling, pollution control devices, increased lifetime of all forms of capital, and methods to restore eroded and infertile soil. Value changes include increased emphasis on food and services rather than on industrial production. Births are set equal to deaths and industrial capital investment equal to capital depreciation. Equilibrium value of industrial output per capita is three times the 1970 world average.

SOURCE: *Limits to Growth*

in 1975, would lead to an "equilibrium state" (see fig. 4):[22]

- **restrict population growth** by reducing average desired family size to two children and making "perfect" birth control universally accessible (population stabilizes at about 6 billion in 2050, after a delay inherent in the age structure of the current population);
- **restrict capital growth** by maintaining average industrial output per capita at the 1975 level and holding the capital investment rate equal to the depreciation rate (excess capacity is used to produce consumer goods and services);
- **reduce resource consumption and pollution generation** per unit of industrial and agricultural output to one-fourth of their 1970 levels (largely through recycling and advanced abatement technologies);
- **divert capital to agricultural production** in order to produce sufficient food for all people, even if such an investment would be considered "uneconomic;"
- **prevent soil depletion and erosion** by using some of the agricultural capital for enrichment and preservation (e.g., composting urban organic wastes and returning them to the land); and
- **extend the average lifetime of industrial capital stock** through improved durability and maintenance, in order to reduce obsolescence and make more capital and resources available for other sectors.

The authors recognized that different combinations of the above policies might be adopted by different societies, and that "[a] society choosing sta-

[22]Ibid., pp. 160-166.

bility as a goal certainly must approach that goal gradually."[23] However, they hastened to add that action must be taken soon: if the implementation of these policies were to be delayed by 25 years, for example, they would not result in an "equilibrium state" (see fig. 5); this implicitly suggests that far more severe measures would be required after that time.

These findings led the authors to call for a "controlled, orderly transition from growth to global equilibrium," but they were vague about the specific actions and tradeoffs this transition would require, explaining that "much more information is needed to manage the transition."[24] Some critics feel that the model's "no growth" bias "can be seen as supporting the interests of the materially well-off" and the rich nations.[25] However, others point out that the equilibrium state necessarily implies a "world-wide radical egalitarian levelling of incomes and property,"[26] yet the MIT team has "almost nothing to say about what should or might happen to poor nations . . . under the policy of no growth."[27] Because of "their deliberate self-restriction to physical properties of the world," according to another critic, "they have chosen to be unconcerned with politics [and] social structure;"[28] *The Limits to Growth* speaks instead of the greater demands that will be placed on "humanity's moral resources."[29] Above all, however, the model's simplification and global aggregation of imperfectly understood factors make it unsuited for generating specific, detailed policy recommendations. This is a limitation shared by other global models:

> The breadth of focus and coherent conceptual development of the world models ensure their utility for clarifying the nature of long-term global problems. However, their limitations render them unsuitable as primary tools of analysis or as tools for detailed analysis of global problems and their solutions.[30]

[23]Ibid., p. 167.

[24]Ibid., p. 180.

[25]Keith L. R. Pavitt, "Malthus and Other Economists: 'Some Doomsdays Revisited,'" in *Models of Doom: A Critique of the Limits to Growth*, H. S. D. Cole (ed.) (New York: Universe Books, 1973), pp. 154-157.

[26]Harvey Simmons, "Systems Dynamics and Technocracy," in *Models of Doom*, pp. 206-207.

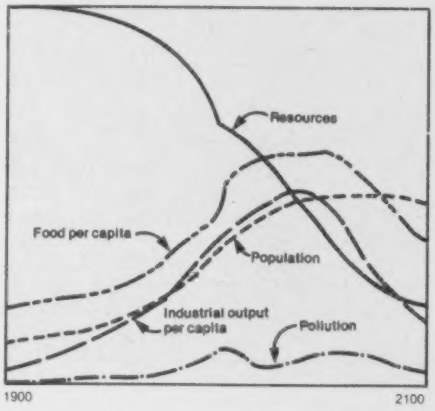
[27]Cole in *World Futures: The Great Debate*, p. 29.

[28]Marie Jahoda, "Postscript on Social Change," in *Models of Doom*, p. 212.

[29]Meadows, et al., *The Limits to Growth*, p. 179.

[30]Jennifer Robinson, "Worlds 2 and 3," in *The Global 2000 Report to the President* (Washington, D.C.: U.S. Council on Environmental Quality and Department of State, 1980), vol. 2, p. 608.

Figure 5.—World 3 Run With Stabilizing Policies Introduced in the Year 2000



If all the policies instituted in 1975 in the previous figure are delayed until the year 2000, the equilibrium state is no longer sustainable. Population and industrial capital reach levels high enough to create food and resource shortages before the year 2100.

SOURCE: *Limits to Growth*

Conclusions of World 3

Within these limits, World 3 arrives at three central conclusions that have been influential in the subsequent "futures debate:"[31]

1. If present growth trends in global population, industrialization, resource depletion, pollution, and food production are allowed to continue unchanged, the limits to growth on this planet will be reached sometime within the next 100 years, resulting in a catastrophic decline in both population and industrial capacity.
2. These growth trends can be altered in such a way as to establish economic stability at levels that are both sustainable into the foreseeable future and capable of satisfying the basic material needs of all the world's people.
3. If the people and nations of the world decide to strive for this equilibrium state, the sooner they start working to attain it, the greater their chances for success will be.

[31]Meadows, Richardson, and Bruckmann, op. cit., pp. 67-68.

Similarly, the technical limitations that restrict the utility of World 3 have proven to be a stimulus for subsequent global models, whose purposes increasingly have been to achieve both greater specificity and greater relevance to the needs of policymakers.

World Integrated Model—Mankind at the Turning Point

Origin and Purpose

The World 3 model achieved most of the objectives set for it by the MIT team and by the Club of Rome, but system dynamics was still viewed with skepticism in traditional scientific and policy circles. As a result, the popularized report on the model, *The Limits to Growth*, was the subject of considerable debate and controversy because of its methods—primarily its radical aggregation of global factors—and because of its vagueness on policy issues. When the club began planning a followup in 1972, therefore, it sought a modeling approach that would accomplish three goals:[12]

- to represent the world as a system of interdependent regions, rather than a single homogeneous unit, and to represent those regions in greater sectoral detail;
- to develop recommendations that would be of more direct relevance to policymakers; and
- to gain greater acceptance from the scientific community by incorporating more "hard data" and, wherever possible, by explicitly employing state-of-the-art theories and methodologies from the relevant academic disciplines.

The model the club chose to support, again with funds from the Volkswagen Foundation, was the World Integrated Model (WIM). This model was developed in parallel by two teams, one led by Mihajlo Mesarovic at Case Western Reserve University in Cleveland and the other by Eduard Pestel (a member of the executive committee of the Club of Rome) at the Technical University in Hannover, West Germany.

The authors first presented their model at a conference for high-level policymakers sponsored by the Woodrow Wilson International Center for Scholars in Washington, D.C., then at the first global modeling conference of the International Institute for Applied Systems Analysis (IIASA) in Austria, and finally at a series of scientific meetings and congresses throughout the world. Only after these formal presentations—and the distribution of technical documentation to selected experts—did they release the popular description of the model in the fall of 1974.

[12]Ibid., pp. 72-74.

Structure and Assumptions

The WIM methodology is based on Mesarovic's "multilevel hierarchical systems theory," which views the world in terms of five interrelated planes or strata:

- **the environmental stratum,** which combines geophysical and ecological factors and corresponds roughly to the natural "carrying capacity," although perhaps too superficially to satisfy some environmentalists;
- **the technology stratum,** which embraces activities whose biological, chemical, or physical terms involve mass and energy transfer;
- **the demographic-economic stratum,** which combines the human population and industrial capital of World 3 and, with the environment stratum, makes up most of the model's content;
- **the group stratum,** made up of sociopolitical institutions, policies, and decisions, which are usually represented as sets of alternative scenarios among which the model user chooses; and
- **the individual stratum,** reflecting personal attitudes and values, again represented by alternative scenarios to be selected by the model user.

According to the theory, these levels ordinarily operate with a fair degree of independence, although they can become highly interactive under "crisis" conditions. The authors therefore feel that their model can help us to understand and predict

the system's behavior in both present and future crises.[33]

The major improvement in the WIM representation of the world system, however, is its greater geographic and economic detail (regionalization and disaggregation). Instead of a single homogeneous world, the model contains 10 regions made up of similar countries (see fig. 6), although in some runs they are grouped in three or four blocs. As a result, WIM can represent varying levels of development and resource endowment, as well as cultural and environmental differences; and it can therefore be used to investigate potential regional (as opposed to global) problems and crises. In addition, because these regions are connected by a trade network, WIM can be used to investigate the potentially mitigating effects of international trade (see fig. 7). Within each region, physical and economic sectors are differentiated into numerous subcategories—85 age groups for population, 19 categories for industrial capital, five for energy capital, two for agricultural capital, and so on. From the point of view of an economist, in fact, WIM is a collection of regional economic models. The resulting mathematical model is quite large: World 1 contained only 40 equations, and World 3 about 200, while WIM (according to its creators) contains over 100,000.[34]

Another improvement, one that is more directly relevant to policy applications, is the model's interactive design. The model user is allowed to estimate social and political behavior by selecting among alternative scenarios in the individual and group strata, thereby manipulating certain variables in such a way as to test a wide range of policy assumptions about energy prices, food exports, capital investments, and development aid. In addition, WIM's various submodels can be used independently to generate and test alternative policies for specific countries and regions. This capability

[33]Jennifer Robinson, "Mesarovic-Pestel World Model," in *The Global 2000 Report to the President*, vol. 2, p. 616.

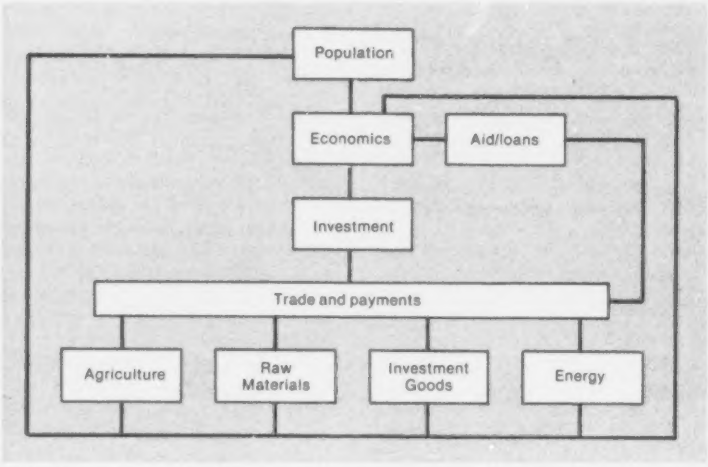
[34]Cole in *World Futures: The Great Debate*, p. 34.

Figure 6.—Regionalization of the World Integrated Model

NOTE: Later versions of World Integrated Model divide regions 1, 5, 6, and 7 into two regions each, for a total of 14 regions; they also have the capability of subdividing these new regions into five subregions each, depending on the level of detail required.

SOURCE: *Mankind at the Turning Point.*

Figure 7.—Block Diagram of the Basic Elements of the World Integrated Model



SOURCE: Command and Control Technical Center.

was in fact one of the stated objectives of the modelers:

> We hoped thus to furnish political and economic decisionmakers in various parts of the world with a comprehensive global planning tool, which could help them to act in anticipation of the crises at our doorstep and of those that loom increasingly large in the distance, instead of reacting in the spirit of short-term pragmatism.[35]

In keeping with this objective, which is shared by the Club of Rome, the WIM team at Case Western Reserve has actively marketed their model, using satellite-telephone patches to make presentations to prime ministers and other officials in at least 18 different nations.

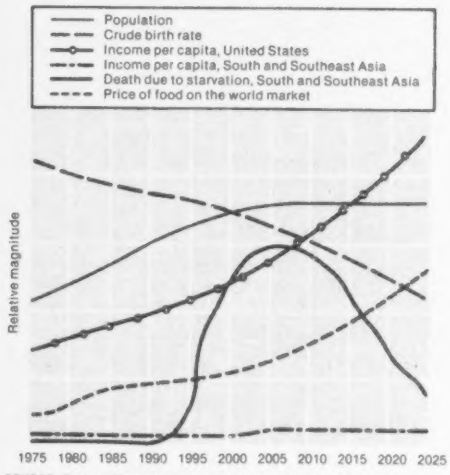
Findings of WIM

The WIM model has shown its versatility in extensive use for policy testing, both to evaluate alternative scenarios within its own assumptions and to test the scenarios and assumptions of other modelers and futurists.[36] Because the purpose and output of the model vary significantly from user to user and run to run, however, it is difficult to isolate any particular "results," although several test runs are illustrative. The reference or "historical scenario" run of the model, based on a continuation of present trends, results in the model output shown in figure 8: a steady increase in the real cost of food on the world market, which would also drive up domestic prices in the United States, and a catastrophic increase in the number of deaths caused by starvation in South Asia. The alternative "isolationist scenario" (fig. 9) indicates that, should the United States act to keep domestic food prices down by restricting exports, starvation in South Asia comes sooner and is even more widespread. In another pair of policy tests (fig. 10), the model output suggests that a policy of low, fixed oil prices leads to a catastrophic economic decline in the developed world when the resource is exhausted, whereas "optimal" price increases (per-

[35]Mihajlo D. Mesarovic and Eduard Pestel, *Mankind at the Turning Point* (New York: Dutton, 1974), p. ix.

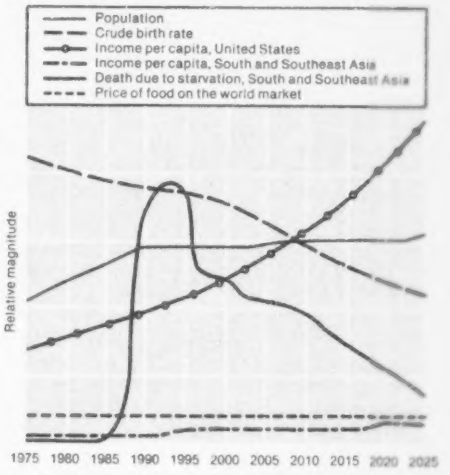
[36]See, for example, Barry B. Hughes and Mihajlo D. Mesarovic, "Testing the Hudson Institute Scenarios" (Washington, D.C.: U.S. Association for the Club of Rome, Sept. 1979), mimeograph.

Figure 8.—WIM Historical Scenario


Population
Crude birth rate
Income per capita, United States
Income per capita, South and Southeast Asia
Death due to starvation, South and Southeast Asia
Price of food on the world market
Relative magnitude
1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025

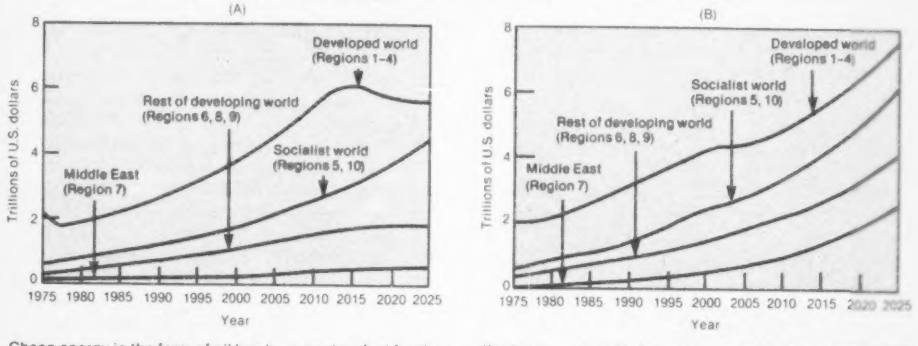
SOURCE: Systems Research Center, Case Western Reserve University.

Figure 9.—WIM Isolationist Scenario


Population
Crude birth rate
Income per capita, United States
Income per capita, South and Southeast Asia
Death due to starvation, South and Southeast Asia
Price of food on the world market
Relative magnitude
1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025

SOURCE: Systems Research Center, Case Western Reserve University.

Figure 10.—Comparison of WIM Low- and Optimal-Price Oil Scenarios


(A)
Developed world (Regions 1–4)
Rest of developing world (Regions 6, 8, 9)
Socialist world (Regions 5, 10)
Middle East (Region 7)
Trillions of U.S. dollars
0 2 4 6 8
1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025
Year
(B)
Developed world (Regions 1–4)
Socialist world (Regions 5, 10)
Rest of developing world (Regions 6, 8, 9)
Middle East (Region 7)
Trillions of U.S. dollars
0 2 4 6 8
1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025
Year

Cheap energy in the form of oil has been a prime fuel for the unprecedented growth of the world economy in the 1950's and 1960's. The dramatic increase in oil prices in 1973 was viewed as a catastrophe. However, computer analysis of our world system model indicates that the continuation of what amounts to overexploitation of oil, spurred by an unreasonably low price, would lead to major dislocations because of the exhaustion of reserves and the lack of motivation to develop substitutes in time. Pursuance of short term objectives would lead to major dislocations in the long run (see A). A much more beneficial development for all concerned results from the "optimal price scenario" in which the price is gradually increased up to the "optimum" level. Such a policy would bring in the substitutes in a more regular fashion while prolonging the reserves. Both exporting and importing regions would fare better (see B). It is only by taking a global and long term view that such a course of development, most beneficial to all concerned, can be identified.

SOURCE: *Mankind at the Turning Point.*

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mitting gradual adaptation and substitution) benefits both oil producers and consumers; a third oil-price scenario (not shown) suggests that increases above the "optimal" level leave *all* regions worse off.[37]

Conclusions of WIM

From these and numerous additional interactions with the model, the authors arrive at several conclusions about the nature of the world system and the management of future development:[38]

- the current crises in agriculture, energy, etc., are not transient but persistent, and represent the first signs of an "oncoming era of scarcity;"
- the solutions to these crises cannot be found through isolated, short-term, or narrowly nationalistic strategies, but only through an integrated global context and "in the spirit of truly global cooperation . . . guided by a rational master plan for long-term organic growth;" and
- "the time that can be wasted before developing such a global world system is running out."

The model indicates that oil, substitutes for oil, and agricultural land will be the greatest constraints on growth. To address these problems, the authors recommend a policy of "organic growth," based on a recognition that the world system is a "collection of functionally interdependent parts."[39] This policy, which would encourage growth where needed and discourage it where it "threatens not only that part but the whole as well," include such specific steps as the following:[40]

- encourage worldwide diversification of industry to achieve a truly global economic system;
- build up the economic base and especially the export potential of the poorest countries so they can pay for food imports;
- give food aid to the poorest countries, but give investment aid only in the form of "intermediate" or appropriate technology; and
- carry out effective social and institutional reforms, because the required economic transfers are impossible under prevailing international economic arrangements.

The authors suggest that unless such steps are taken, spreading regional collapse and international tension will, like falling dominoes, eventually reach the developed world. If these and other steps are taken, on the other hand, "the world growth rates implied by [WIM's] computer results are much closer to those of Kahn and Wiener than to those of Meadows and Forrester."[41]

U.S. Government Use of WIM

More recently, former members of the modeling team have designed a specially tailored version of WIM for the U.S. Department of Defense.[42] The model, which is fully operational, is maintained and operated by the Command and Control Technical Center (CCTC) in support of the Plans and Policy Directorate (J-5) of the Joint Chiefs of Staff. J-5 is currently creating a new division, specifically devoted to long-range analysis, which will use the model to develop projections of global systems behavior for use in long-range national security planning. At present, the model is being developed to provide data on political, economic, and demographic conditions under various subcontingencies of four basic scenarios or "future worlds" defined by J-5:

- "A—muted bipolarity," essentially a reference run based on current trends and international relations;
- "B—superpower dominance (conflict mode)," including contigencies representing different levels of East-West conflict;
- "C—superpower dominance (cooperation mode);" and
- "D—devolution of power," representing a future in which the superpowers must share world power with other groups of nations, and including contingencies for potential North-South conflicts, such as an oil embargo.

[37]Meadows, Richardson, and Bruckmann, op. cit., p. 83.
[38]Mesarovic and Pestel, op. cit., pp. 85, 157.
[39]Ibid., pp. 5, 66.
[40]Cole in *World Futures: The Great Debate*, pp. 35-36.
[41]Ibid., p. 36.
[42]Material in this and the following paragraph is based on interviews with Col. Wilbert Jenkins, J-5, and Maj. Gary Knutson, CCTC; see also *World Integrated Model Multilevel Hierarchical Theoretic Concepts*, CCTC Technical Memorandum TM 197-79 (Washington, D.C.: U.S. Defense Communications Agency, June 15, 1979).

These WIM projections will become an input to the Joint Long-Range Strategic Appraisal beginning with its 1982 revision. CCTC also plans a complete update of its data base (facilitated by a new software package) and further refinements in WIM itself that may make it a more flexible tool for determining future military requirements. For instance, CCTC's version of WIM contains 12 geographical regions rather than 10 and will soon be expanded to 14, with the further capability of subdividing each new region into five subregions; it also contains 87 rather than 85 age groups and (for the United States and Soviet Union) a labor-skills submodel that further divides the population into male or female and urban or rural; and there have been similar refinements in the agricultural and materials submodels. These improvements create data problems, however, since reliable data are not available for many subregions and sectors. CCTC is working with the Bureau of Mines to update and expand the data base for the materials sector; in addition, J-5 has instructed CCTC to contact other Federal agencies about possible coordination of global modeling and strategic assessment activities. Such coordination might be facilitated in at least two cases by the fact that the Department of Agriculture, as well as the Bureau of Mines, is already using a version of WIM.

Latin American World Model—Catastrophe or New Society?

Origin and Purpose

When the Club of Rome presented the preliminary results of World 3 at a 1970 meeting in Rio de Janeiro, the reaction of the mostly Latin American audience was strongly negative. They felt that predictions of global crises, based on extrapolation of present trends and arrangements, reflected a parochial developed-world perspective; for two-thirds of the world's people such crises are already at hand. The audience refused to accept scenarios that implicitly curbed development and widened the income gap, and they felt that policies aimed at achieving a state of global equilibrium would merely ensure that the present disparities and inequities in the world system are perpetuated. They resolved, therefore, to design a model of an egalitarian "ideal society" in which basic human needs (not profits) would be the basis for resource allocation. The purpose of the model is to demonstrate the material viability of such a society, and thereby to demonstrate "that the different countries and regions of the world (particularly the poorest) could reach the goals we advocate in a reasonable period of time," relying primarily on their own human and economic resources.[43]

This global modeling effort was carried out at the Fundacion Bariloche in Argentina, with principal support from the International Development Research Center in Ottawa, and was first presented at the second IIASA modeling conference in Berlin in October 1974. An expanded version of the model, developed for the International Labor Organization (ILO), was warmly received at the 1976 World Employment Conference in Geneva, where "basic needs" were formally adopted as a major target of development.[44] The model continues to have considerable impact through United Nations organizations, including the United Nations Educational, Scientific, and Cultural Organization (UNESCO) and the United Nations Industrial Development Organization (UNIDO) as well as ILO, and it is by far the most popular global model among scientists and decisionmakers in the Third World.[45]

Unlike World 3 and WIM, which provide conditional descriptive forecasts of global trends, the Latin American World Model (LAWM) is openly and insistently normative—it is not concerned with "predicting what will occur if the contemporary tendencies of mankind continue, but rather with sketching a way of arriving at the final

[43]Amilcar O. Herrera, et al., *Catastrophe or New Society? A Latin American World Model* (Ottawa: International Development Research Center, 1976), p. 8.

[44]Cole in *World Futures: The Great Debate*, p. 39.

[45]Meadows, Richardson, and Bruckmann, op. cit., p. 92.

goals of a world liberated from underdevelopment and misery."[46] Its purpose is not to demonstrate that certain changes might bring the present world system into equilibrium, but rather "to show the feasibility of solving the fundamental problems through deep socio-political changes."[47] The model is also distinguished by its emphasis on the ideological issues involved in global modeling: the modeling team was composed of humanistic socialists,[48] and on questions of development and redistribution they "explicitly take up a stance favourable to the Third World in general, and to Latin America in particular."[49]

Structure and Assumptions

The LAWM team's goals and purposes lead them to include some rather unusual assumptions in the structure of their model. For instance, the model divides the world into four regions (later 15), each of which is treated as an economic unit, which "presupposes total collaboration between the countries forming it."[50] The model contains "simplistic" trade linkages: the contribution of international trade relative to regional gross national product (GNP) is held constant at the 1970 level, and all trade deficits are eliminated by 2000.[51] Instead, each region satisfied basic needs through "autarchy," using almost exclusively local economic resources. However, these resources are assumed to be available in unlimited quantities and at constant cost: after a static analysis of current resource data, the modelers conclude that "the environment and its natural resources will not impose barriers of absolute physical limits on the attainment of [an ideal] society," at least not within a "historically significant time-scale."[52] As a result, they do not include these physical factors in the computer model, and in this specific their model reflects a technological optimism akin to Herman Kahn's.

However, the authors do assume a radical change in the sociopolitical factors that control patterns of resource use—i.e., an equal distribution of consumption between regions and a total, egalitarian redistribution of income within regions. In addition, the model includes no assumptions about population policies, although it does include several untested assumptions about the effect of living conditions on demographic change. LAWM also appears to assume automatic growth in productivity through technological progress, at no cost, at rates between 0.5 and 1.5 percent annually depending on the sector.[53]

LAWM is essentially an economic model that operates through optimization procedures; i.e., it has five production sectors representing basic needs—food, housing, education, capital goods, and other goods and services—to which labor and capital are allocated through optimal control techniques in such a way as to maximize life expectancy at birth, which is taken to be the best indicator of general living conditions. These calculations proceed independently for each region from 1960 to 2060, but all countries are assumed to follow optimal policies after 1980.

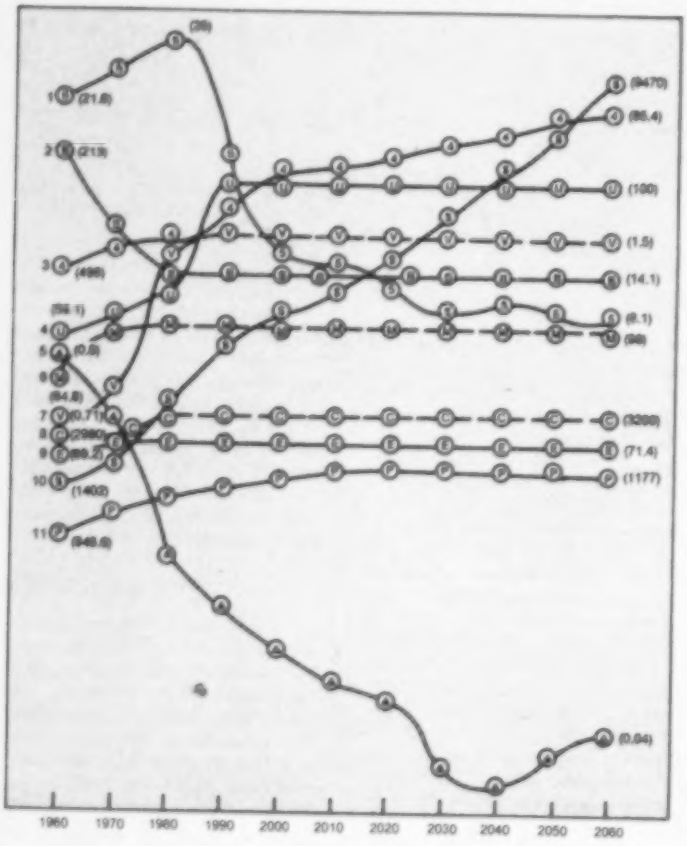
Findings of LAWM

The standard or reference run of this optimization model indicates that all regions except Asia can reach their basic needs targets within 30 years. Developed nations (including the Communist world) "can reach high levels of well-being even if their economic growth rate is reduced drastically in the future" (fig. 11); in reality, economic growth is restricted to between 1 and 2 percent—far below the developed region's capacity for growth—which the authors acknowledge "assumes a political decision."[54]

Latin America could fulfill basic needs by the early 1990's by maintaining a relatively high investment rate, particularly in housing and education (fig. 12). The output for Africa closely resembles that for Latin America, although basic needs are not met until 2008 and some shortfalls occur in the housing sector.

[46]Amilcar O. Herrera, *Proceedings of the 2d IIASA Global Modeling Conference* (Berlin, 1974), quoted by Meadows, Richardson, and Bruckmann, op. cit., p. 91.
[47]Hugo D. Scolnik, et al., "The Bariloche Model," in Meadows, Richardson, and Bruckmann, op. cit., p. 247.
[48]Jennifer Robinson, "The Latin American World Model," in *The Global 2000 Report to the President*, vol. 2, p. 647.
[49]Cole in *World Futures: The Great Debate*, p. 48.
[50]Herrera, et al., op. cit., p. 44.
[51]Robinson, "The Latin American World Model," p. 642.
[52]Herrera, et al., op. cit., p. 8.
[53]Robinson, "The Latin American World Model," pp. 639, 643.
[54]Herrera, et al., op. cit., pp. 87, 100-101.

Figure 11.—LAWM Standard Run for Developed Nations

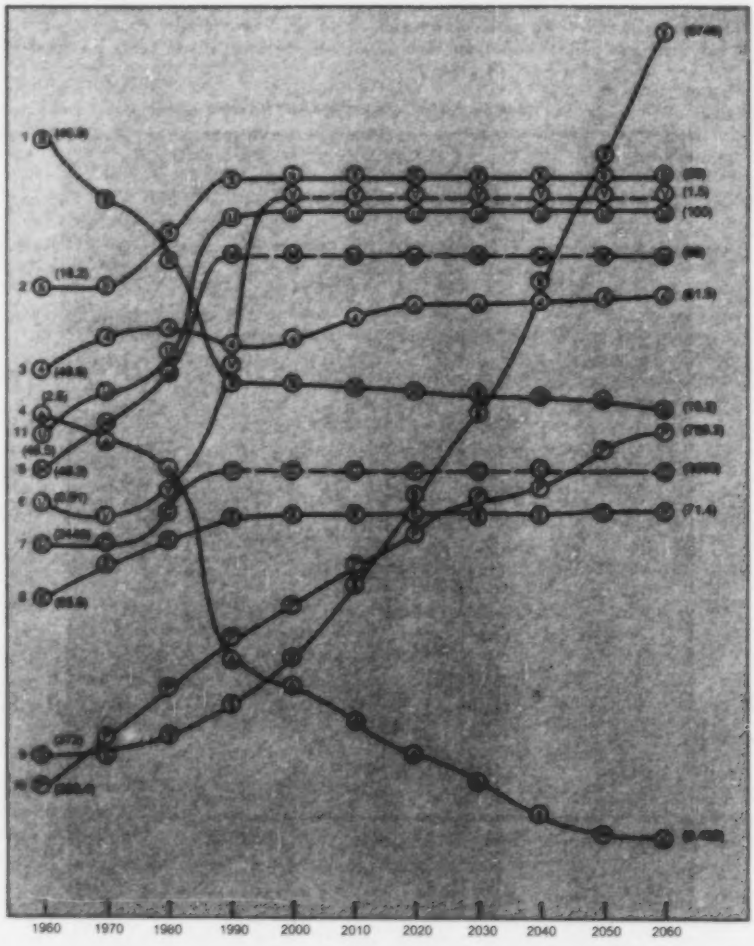


Key

1 (5) Percent GNP allocated to sector 5
2 (B) Birthrate
3 (4) Percent GNP to other goods and services
4 (U) Urbanization
5 (▲) Population growth rate
6 (M) Enrollment
7 (V) Houses per family
8 (C) Total calories per capita
9 (E) Life expectancy
10 ($) GNP per capita
11 (P) Total population

SOURCE: *Catastrophe or New Society?*

Figure 12.—LAWM Standard Run for Latin America



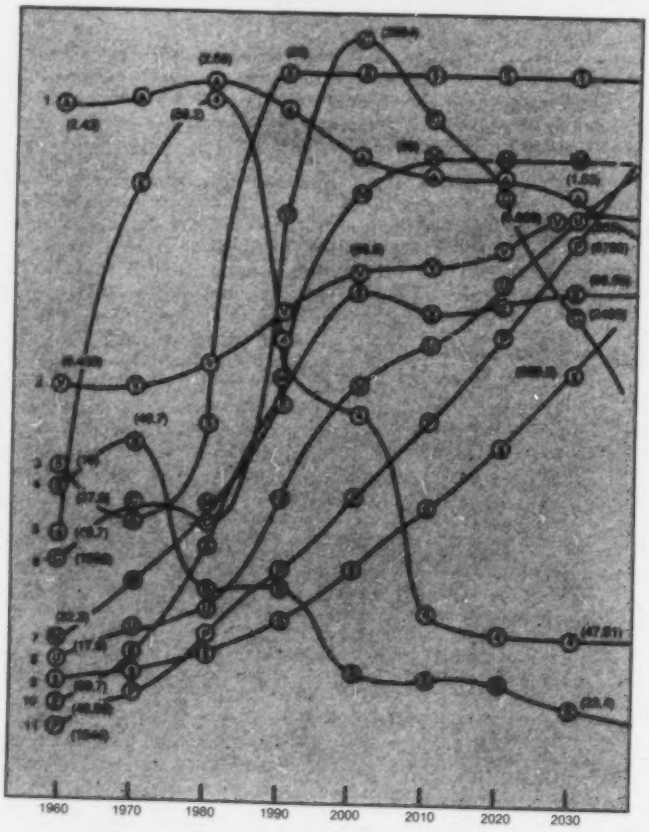
Key:

1 (B) Birthrate
2 (5) Percentage of GNP allocated to sector 5
3 (4) Percentage of GNP allocated to sector 4
4 (▲) Population growth rate
5 (M) Enrollment
6 (V) Houses per family
7 (C) Total calories
8 (E) Life expectancy
9 ($) GNP per capita in 1960 dollars
10 (P) Total population
11 (U) Urbanization

SOURCE: *Catastrophe or New Society?*

Asia is unable to satisfy basic needs even with optimal allocation of its resources. The model output (fig. 13) closely resembles the global projections of World 3 and the WIM output for Asia (figs. 3, 8, and 9). This occurs, the modelers explain, because "the food sector fails"—all available land in Asia is under cultivation by 2010, and despite massive investments the food sector can-

Figure 13.—LAWM Standard Run for Asia



Key:

1 (▲) Population growth rate
2 (V) Houses per family
3 (5) Percentage of GNP allocated to sector 5
4 (B) Birthrate
5 (4) Percentage of GNP to other goods and services
6 (C) Total calories per capita
7 (M) Enrollment
8 (U) Urbanization
9 ($) GNP per capita in 1960 dollars
10 (E) Life expectancy
11 (P) Total population

SOURCE: *Catastrophe or New Society?*

not keep up with population growth; daily food intake peaks at less than 3,000 calories per capita in 2008 and declines steadily thereafter. (These investments would also divert resources from the satisfaction of other basic needs, and they would probably prevent economic growth if investment in capital goods were not fixed at 25 percent.) Only an effective population policy and the use of nonconventional foodstuffs, both of which the authors advocate, could avoid catastrophe in Asia under these conditions.

The policy tests conducted with LAWM indicate that capital transfers from the industrialized countries (in isolation from other measures) would have little effect on the above outcomes, but they also reveal that both technological progress and internal income redistribution are vital to achieving regional goals.

- In the "international solidarity" run, the developed nations transfer capital aid to Africa and Asia at a rate that rises from 0.2 percent of GNP in 1980 to 2.0 percent in 1990 and thereafter. The result is higher investment rates and faster economic growth in the industrialized nations (in order to compensate for the aid), but very little effect on the time needed to satisfy basic needs elsewhere and a negligible impact on the food shortage in Asia.
- In the "technological stagnation" run, on the other hand, growth in economic production due to technical progress falls to zero between 1980 and 2000 and remains there. The outcome is disastrous in every region except the developed nations. Latin America requires a longer period of time to satisfy basic needs, particularly food and housing, and in Africa and Asia "the economic system finally collapses" sometime between 1990 and 2020 as population steadily outstrips production.
- By far the greatest difference in results, however, comes from the "historical" run, in which the assumption of egalitarian intraregional redistribution is replaced by a pattern of consumption that reflects current income distributions and socioeconomic structures. To satisfy basic needs in the same period of time under these conditions would require economic growth rates of 10 to 12 percent in the developing countries, rates which "are in fact impossible to attain." The authors conclude that "at the very best" their goals would be delayed by two or three generations, and would require 3 to 5 times more resources, under these conditions.[55]

Conclusions of LAWM

The conclusions the LAWM team draws from its interactions with the model do not always reflect the above results (apparent discrepancies are noted in parentheses):[56]

- "it is possible to control population growth to the point of equilibrium by raising the general standard of living" (population stabilizes only in the developed regions, and is still growing globally at a rate of 1.1 percent per year in 2040);
- "if the policies proposed here are applied, all of humanity could attain an adequate standard of living within a period little longer than one generation" (this is true for Asia only with an effective population policy and considerable development aid);
- "this equilibrium could be achieved on a global scale well before the earth's capacity to produce food—the only foreseeable physical limitation within the time horizon of the model—is fully exploited even if food production continues to be based on currently available technology" (the model assumes considerable technical progress at no cost in agriculture and all other sectors, and fails to achieve its goals if technology stagnates);
- "[the] obstacles that stand in the way of the harmonious development of humanity are not physical or economic in the strict sense, but are essentially sociopolitical;" and
- "[the] goals are therefore [to be] achieved . . . by a reduction of nonessential consumption; increased investment; . . . the rational use of land . . . the egalitarian distribution of basic goods and services; and . . . the implementation of an active policy to eliminate deficits in international trade."

[55] Ibid., pp. 106-107.
[56] Ibid., p. 107.

United Nations Input-Output World Model—The Future of the World Economy

Origin and Purpose

Like LAWM, the United Nations Input-Output World Model (UNIOWM) represents a Third World reaction to the unpalatable conclusions of *The Limits to Growth*. However, its central concern is not the satisfaction of basic needs, but rather the narrowing of the income gap between the rich and poor nations. The model was commissioned in late 1972 by the Centre for Development Planning, Projections, and Policies (CDPPP), a U.N. agency responsible for long-range integrated planning. Initial financial support came from the Government of the Netherlands, and subsequent funding was obtained from the U.N., the Ford Foundation, and the National Science Foundation. Wassily Leontief, the project director, outlined the concepts behind the model in his acceptance speech for the Nobel Prize in economics in 1973; the work of collecting data and building the model was carried out by Anne Carter, Peter Petri, and others at Brandeis University. Petri presented the model at the Fifth IIASA modeling conference in September 1977, shortly after *The Future of the World Economy* was released in New York.

The study was conducted under U.N. auspices and direction. Although its findings did not represent official U.N. recommendations, the model's primary purpose was to determine whether physical or environmental limits would pose a significant barrier to the economic growth targets set by the U.N.'s International Development Strategy, which had been proposed by the General Assembly in 1970 as the basis for the Second Development Decade. As modified and expanded by various U.N. agencies, these targets include the following:

- reducing the average income ratio between the developing and developed countries by almost 50 percent, from 12:1 to 7:1;
- improving internal income distribution to eradicate mass poverty;
- creating 1 billion new jobs in the developing world by 2000;
- satisfying the basic needs of all people;
- increasing food production in developing countries by at least 4 percent per year;
- increasing the developing nations' share of the world market in manufacturing to 14.3 percent by 1985 and 25 percent by 2000; and
- achieving a new international economic order (NIEO), including stabilized commodity prices, increased financial and technology transfers, open markets for the less developed countries' (LDC) exports, and a code of conduct of transnational enterprises.

Structure and Assumptions

The authors describe UNIOWM as "basically a general-purpose economic model and thus applicable to the analysis of the evolution of the world economy from other points of view,"[57] notably the environmental. However, Leontief has cautioned that:

> We cannot predict the future of the world economy. However, we can rule out of our expectations future scenarios that are internally inconsistent and thus impossible.
>
> To rule out internally inconsistent expectations we need to construct a model that guarantees internal consistency . . . by visualizing the world as a system of interdependent process in which each process . . . generates certain output and absorbs a specific combination of input.[58]

The rigorous accounting required by this input-output analysis forces the model to balance the growth of one economic sector against its effect on other sectors; similarly, imports and exports in one region must be balanced against the imports and exports of other regions. This technique also permits "an unusual degree of detail" in representing particular industries or regions, which is "advantageous" because of its "relatively specific policy significance."[59] On the other hand, critics have

[57] Wassily Leontief, Anne Carter, and Peter Petri, *The Future of the World Economy: A United Nations Study* (New York: Oxford, 1977), p. 7.

[58] Wassily Leontief, "Structure of the World Economy: Outline of a Simple Input-Output Formulation" (Nobel Memorial Lecture), *American Economic Review*, December 1977, p. 823.

[59] Leontief, Carter, and Petri, op. cit., p. 8.

questioned whether this level of explicit detail is worthwhile or justifiable, particularly since it demands an enormous amount of data, much of which had to be adapted from other information and data bases.[60] UNIOWM's population sector, for example, merely assumes the projections prepared by the U.N. Population Division in 1973 (see app. A).

The model divides the world into 15 regions composed of fairly homogeneous economies, although for purposes of interpretation and presentation of results these regions are further aggregated in three categories: developed nations (eight regions), resource-rich LDCs (three regions), and resource-poor nations (four regions). Each region's economy contains 45 sectors of economic activity, described by 175 equations with 229 variables. Prices are calculated in a separate submodel, and (as in LAWM) the representation of international trade has been kept "almost artificially simple."[61] The environmental sector includes eight pollutants and five types of abatement activities, but the model does not reflect the effect of development on ecological systems, nor does it contain any other feedback loops; "it cannot, in any sense, be viewed as a dynamic model."[62] The model's equations are solved simultaneously, usually at 5-year intervals, in order to provide "snapshots" of the world in 1980, 1990, and 2000.

The model can be applied to a wide variety of tasks, but its utility is limited by its large data requirements and by the many controversial assumptions that have been included. This has led one critic to conclude that:

> The huge number of assumptions made in estimating time trends for input-output matrices makes for confusion when it comes to considering the model as a whole. There are so many assumptions that one is hard put to evaluate the reasonableness of the total picture.[63]

Nevertheless, the model could be and has been used for a wide range of policy tests that reflect the interests of the modelers and the organizations that commissioned them.

Findings of UNIOWM

The study's optimistic findings, particularly that "no insurmountable physical barriers exist within this century to the accelerated development of the developing regions" and that "pollution . . . is a technologically manageable problem,"[64] received widespread attention in the media, where it was sometimes reported that UNIOWM "discredited" *The Limits to Growth*. However, the authors have cautioned that the model "cannot settle, and was not designed to settle, the many fundamental questions raised in *The Limits-to-Growth* debate."[65] And in fact the optimism of these general statements is not supported by the specific results of most of UNIOWM scenarios.

Policy tests conducted for the UN have included a number of different scenarios relating to economic growth rates and per capita income gaps.

- The "old economic order" scenario is based on historical trends in internal and external investment and existing international economic arrangements. Income per capita grows in all three categories of nations but income gaps increase, despite decelerating growth in the developed regions after 1990, and some LDCs would face an absolute decline in living standards (see fig. 14). This scenario "turns out to be rather pessimistic," according to the authors, and because of its dim economic prospects for the developing regions it is "downplayed in the UN documentation."[66]
- The standard run, based on the minimum growth targets of the International Development Strategy (IDS), also turns out to be relatively pessimistic. Because of their higher rates of population growth, accelerated economic growth in the LDCs does not lead to corresponding gains in GNP per capita. The income gap between developed and less developed regions remains at the current 12:1 ratio.

[60]Sam Cole, *Global Models and the International Economic Order: A Paper for the UNITAR Project on the Future* (New York: Pergamon Press, 1977), p. 22; and Jennifer Robinson, "U.N. World Model," in *The Global 2000 Report to the President*, vol. 2, p. 649.

[61]Robinson, "U.N. World Model," p. 652.

[62]Meadows, Richardson, and Bruckmann, op. cit., p. 167; a similar criticism could be made of WIM.

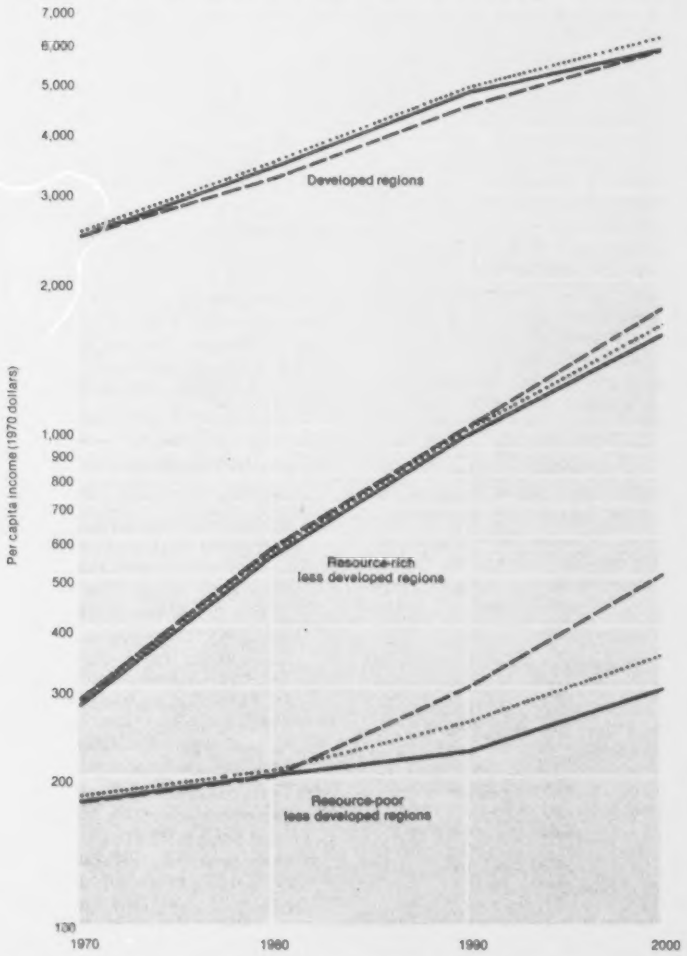
[63]Robinson, "U.N. World Model," p. 652.

[64]Leontief, Carter, and Petri, op. cit., pp. 48-49.

[65]Peter Petri, "An Introduction to the Structure and Applications of the United Nations World Model," *Applied Mathematical Modeling*, vol. 1, No. 5, June 1977, p. 262.

[66]Leontief, Carter, and Petri, op. cit., p. 73; Robinson, "U.N. World Model," p. 653.

Figure 14.—Regional Economic Growth Under Three UNIOWM Scenarios



Projected economic development of the developed regions of the world, the resource-poor less developed regions and the resource-rich less developed regions is shown to the year 2000 under the old-economic-order scenario (*solid black lines*), the new-economic-order scenario (*broken black lines*) and the arms-limitation scenario (*dotted lines*). For the resource-poor less developed regions the levels of per capita income and consumption (not shown) grow much faster under the arms-limitation scenario than under the old-economic-order scenario, but not so fast as under new-economic-order scenario, where income targets are prespecified.

SOURCE: Leontief, "The World Economy of the Year 2000," *Scientific American* 243.3, September 1980, p. 231.

- Four additional runs were then conducted by altering the standard or IDS scenario in such a way as to reflect more optimistic assumptions about: 1) resource endowments; 2) increased foreign aid from the developed regions; 3) fewer constraints on balance-of-payment deficits; and 4) faster agricultural investments to achieve food self-sufficiency in low-income Asia.

None of these scenarios, however, was capable of producing the desired reduction in per capita income ratios. In two final scenarios, therefore, the authors preset the model in such a way as to roughly halve the income gap by 2000 and close it completely by about 2050, and then solved its equations to determine the investment and growth rates that would produce the desired results:

- Scenario "C," based on the U.N.'s "low" population growth projections (see app. A), requires a 6.9 percent GNP growth rate in the LDCs to reduce the income ratio to 7.15:1 by 2000.
- Scenario "X," based on the U.N.'s "medium" population projections, requires an even higher GNP growth rate of 7.2 percent in the LDCs and reduces the income ratio only to 7.69:1. Scenario "X" also requires a fivefold increase in overall agricultural output in the developing regions, including a nearly tenfold increase in resource-poor Latin America.

In subsequent policy tests, UNIOWM has been used to examine the economic consequences of mineral- and energy-conservation strategies. A study of the future production and consumption of nonfuel minerals, based on the resource conservation strategies of the Economic Council of Canada, is nearing completion but has yet to be publicly documented.[67] Another study, conducted for the U.S. Department of Commerce, compares the "old economic order" scenario with an "energy conservation" scenario based on the maximum reasonable reduction in fossil fuel consumption over the next 20 years through the substitution of labor and capital for energy. It revealed that energy conservation could reduce the balance-of-payments deficits of both developed regions and resource-poor LDCs and allow increased GNP growth in the latter, but that the capital requirements for conservation would require a 17- to 23-percent increase in the savings rate.[68]

More recently, Leontief has conducted two studies of the economic implications of the NIEO and of worldwide military spending, with funding from the U.N. and from American disarmament organizations.[69] In the NIEO scenario, the resource-poor LDCs are allowed to import whatever quantities of goods and services are required to reduce income ratios by 50 percent by the year 2000, with their balance-of-payments deficits—up to 75 percent of their imports—to be financed by "extraordinary credits" from the developed regions and resource-rich LDCs, carrying a nominal 5-percent interest rate. The model output for this scenario (see fig. 14) shows that the developed regions, which would have to "work overtime . . . to provide [these] huge amounts of economic aid," would have a higher GNP but lower per capita consumption in 2000, at which time they would be allocating 3.1 percent of their total GNP to development assistance. Leontief himself doubts that such a plan could be implemented:

> On the whole this projection of the future development of the world economy under the new economic order suggests that the practical possibility of carrying out such an optimistic program must be seriously questioned.[70]

As an alternative, Leontief proposes an "arms limitation" scenario, noting that the current half-trillion-dollar annual worldwide defense spending represents "the largest existing economic reserve that might be utilized to accelerate the growth of the resource-poor less developed regions." Where the "old economic order" scenario assumed that all regions would continue to devote the same percentage of their respective GNPs to defense that they had in 1970, the "arms limitation" scenario assumes that by 2000 the defense expenditures of the United States and the Soviet Union would be reduced by one-third, and that all other regions

[67]Meadows, Richardson, and Bruckmann, op. cit., p. 175; Robinson, "U.N. World Model," p. 653.

[68]Anne P. Carter and Alan K. Sin, "An Energy Conservation Scenario for the World Model," prepared for the Bureau of International and Economic Policy, U.S. Department of Commerce, November 1977, p. 2.

[69]Meadows, Richardson, and Bruckmann, op. cit., p. 175.

[70]Wassily W. Leontief, "The World Economy of the Year 2000," *Scientific American*, vol. 243, No. 3, September 1980, p. 230.

would reduce defense spending 25 percent by 1990 and 40 percent by 2000. The savings realized in each region would first be used to satisfy its own civilian needs, but the developed regions would allocate 15 percent of their savings to development aid by 1990 and 25 percent by 2000. The model output for this scenario (see fig. 14) indicates that per capita income and consumption in the resource-poor LDCs would increase far faster than under the old economic order. Since developed-region defense savings would be given to LDCs in the form of direct aid, their balance-of-payments deficits would also be far smaller. Based on a comparison of these scenarios, Leontief concludes that:

> . . . the reallocation of economic resources arising from the kind of international arms-limitation agreement that has been suggested repeatedly, both formally and informally by individuals and organizations inside and outside the U.N., is by far the most promising of the three schemes for world economic development.[71]

Conclusions of UNIOWM

The results of these numerous UNIOWM scenarios suggest, in general, that the economic prospects of the resource-poor LDCs are not very optimistic. The growth rate targets of the U.N.'s Second Development Decade are insufficient to begin closing the income gaps between developed and developing regions when population increases are taken into consideration. The limits imposed by mineral resources, agriculture, and the environment are not insurmountable and could be overcome through appropriate policies and investments; but "the principal limits to sustained economic growth and accelerated development are political, social and institutional in character."[72] To achieve accelerated development, therefore, two general conditions are considered necessary:

- far-reaching internal reforms in the LDCs, including often drastic changes in sociopolitical institutions and economic policies—between 30 and 40 percent of GNP must be used for capital investment, particularly in the agricultural and export sectors, and both equitable income redistribution and increased public-sector participation are needed to increase the effectiveness of these investments; and
- significant reforms in the international economic order, aimed at reducing the potentially large balance-of-payments deficits in the developing regions—stabilizing commodity markets, stimulating exports of manufactured goods from the LDCs, and increasing financial transfers from the developed regions and resource-rich LDCs.

Neither of these conditions, taken separately, is sufficient to ensure a favorable outcome: "Accelerated development leading to a substantial reduction of the income gap between the developing and the developed countries can only be achieved through a combination of both of these conditions."[73]

[71] Ibid., p. 231.

[71] Leontief, Carter, and Petri, op. cit., p. 48.
[72] Ibid., p. 11.

Global 2000—Entering the 21st Century

Global 2000 is a global modeling study, rather than a "global model" in the same sense that World 3, WIM, LAWM, or UNIOWM are. Its projections result not from a single, integrated model but rather from a collection of sectoral models, independently developed or adopted by various Federal agencies and other organizations, plus a number of projections based on analytical techniques other than computerized simulation models. Despite the very limited degree of interaction among the sectors and agencies, however, and despite the frequent lack of consistency in their various assumption and data bases, these sectoral "submodels" collectively provide the U.S. Govern-

ment with the same type of projections that the other more integrated global models produce for their users.[74]

Origin and Purposes

Global 2000 was carried out by an interagency task force of the U.S. Government in response to a directive issued by former President Carter in his environmental message to Congress on May 23, 1977:

> Environmental problems do not stop at national boundaries. In the past decade, we and other nations have come to recognize the urgency of international efforts to protect our common environment.
>
> As part of this process, I am directing the Council on Environmental Quality and the Department of State, working in cooperation with . . . other appropriate agencies, to make a one-year study of the probable changes in the world's population, natural resources, and environment through the end of the century. This study will serve as the foundation of our longer-term planning.[75]

This mandate, as interpreted by the Global 2000 task force, imposed dual objectives on the study: its purpose was not only to "identify [future] problems to which world attention must be directed," but also "to identify and strengthen the Government's capability for longer-term planning and analysis."[76] The resulting report, released in July 1980, addressed both of these goals, although relying on the Government's existing capability may have detracted from the accuracy and usefulness of the resulting projections. According to a *Science* editorial:

> A reading of portions of the report produced after 3 years reveals more about the functioning of the federal government than it conveys new reliable information about the future of the world.[77]

Various Federal agencies are already conducting a considerable amount of long-term analysis and planning, and a number of them have the capability to produce projections based on extensive data bases and sophisticated sectoral models, many of them computerized. These existing tools and procedures (and the skilled personnel who use them) represent the "present foundation" of the Government's long-range global planning—they embody the assumptions on which current analysis is based, and they are actually being used as at least a partial basis for current planning and decisionmaking. As a result, the study plan chosen by the task force was "to develop trend projections using, to the fullest extent possible, the long-term global data and models routinely employed by the Federal agencies."[78]

However, they found that "each agency has its own idiosyncratic way of projecting the future," based on its individual planning requirements and area of responsibility.[79] As a result, each agency's projections tend to focus on a single factor (such as population, food, or energy) without adequately considering the feedback involved in a system where these factors are interacting variables. Furthermore, although these separate projections "have generally been used by the Government and others as though they had been calculated on a mutually consistent basis," the different agencies' models "were never designed to be used as part of an integrated, self-consistent system."[80] This leads to one of the study's basic findings:

> To put it more simply, the analysis shows that the executive agencies of the U.S. Government are not now capable of presenting the President with internally consistent projections of world trends in population, resources, and the environment for the next two decades.[81]

Despite these deficiencies, Global 2000 presents the most comprehensive and consistent set of projections yet produced by the U.S. Government, and it represents the first attempt to make such

[74]Gerald O. Barney, study director, *The Global 2000 Report to the President: Entering the Twenty-first Century* (Washington, D.C.: U.S. Council on Environmental Quality and Department of State, 1980), vol. 3, pp. v-vi.
[75]Jimmy Carter, *The President's Environmental Program 1977* (Washington, D.C.: U.S. Government Printing Office, 1977), p. M-11.
[76]Barney, *The Global 2000 Report to the President*, vol. 1, p. 6.
[77]Philip H. Abelson, "The Global 2000 Report," *Science*, vol. 209, No. 4458, Aug. 15, 1980, p. 761.
[78]*The Global 2000 Report to the President*, vol. 1, p. 6.
[79]Ibid., vol. 2, p. 454.
[80]Ibid.
[81]Ibid.

projections on a coordinated, integrated basis. The task force has been disarmingly frank and forthcoming in their analysis of "the Government's global model," and their discussion of its current weaknesses points to a number of ways in which existing long-range analysis and planning tools can be improved. Several of the models have in fact been modified or expanded in the last 3 years, often in response to problems identified by the task force, although many problems still remain.[82] The task force cautions, however, that "in the absence of ongoing institutional incentives to address cross-sectional interactions, the present form of the government's global model is not likely to change significantly in the foreseeable future."[83]

Structure and Assumptions

For the purposes of Global 2000, the study team imposed a "special limited discipline," within the time and resource constraints of the study, under which: 1) the assumptions, structures, and projections of the agencies' sectoral submodels were made "more mutually consistent" and 2) the output from one sector was used as the input for another "whenever this was readily feasible."[84] Despite these efforts, however, the Government's model has almost no feedback loops and remains at best "quasi-integrated," with the result that, "if anything, the severity of the effects of these basic trends may be understated."[85] In addition, the submodels employ different patterns of regionalization, varying from as few as five to as many as 28 regions, with a similar variation in the degree of detail provided.[86] This not only makes coordination difficult but also leaves the projections without a consistent geographic reference for policy analysis.

Furthermore, there are numerous major inconsistencies in the values assigned to the same variable in different sectoral submodels, reflecting mutually contradictory agency assumptions about the behavior of crucial factors.[87] The population sector, for example, assumes that birth rates in LDCs will decline because of continued moderate socioeconomic development, whereas the agricultural and economic projections indicate only marginal increases in global food and GNP per capita, with real declines in some LDCs—hardly reflecting moderate socioeconomic development.[88] Similarly, the GNP submodel assumes that the real price of wheat will *decrease* by 0.6 percent per year and that the real price of oil will remain constant during the early 1980's, whereas the food and energy projections indicate real price *increases* of 2.1 and 5.0 percent per year, respectively, over roughly the same period.

Far more serious, however, is the absence of any consistent accounting of capital or resource allocations in *any* of the sectoral submodels. This leads to what the report calls "significant omissions and double-counting"—in effect, the model recognizes no conflicts from competing demands or uses, and it places no constraints on the amount of capital and resources available to each sector.[89] Under these conditions, the same acre-foot of water is assumed to be available for both irrigation and energy development, just as the same barrel of oil is assumed to be available for transportation, energy generation, and petrochemical feedstock.

Different sectors also contain contrasting or contradictory assumptions about the course of public policy, despite the report's frequent repetition of the caveat that its trend projections are made *"under the assumption that present policies and policy trends continue without major change."*[90] The most significant exception to this rule comes in the population projections, which are based on the assumptions of: 1) continued socioeconomic progress despite marginal gains in food and GNP per capita in the LDCs; and 2) adoption of family planning policies in all countries and major extensions of existing programs, especially in rural areas. The other sectoral projections, however, are based on equally significant policy assumptions, including the following:[91]

[82]Ibid., vol. 2, p. 460 n. 2.
[83]Ibid., vol. 2, p. 461.
[84]Ibid., vol. 2, p. 452.
[85]Ibid., vol. 2, pp. 456, 481.
[86]Ibid., vol. 2, pp. 485 n. 1, 478; see also table 14-3, p. 479, and the methodological maps following p. 442.
[87]Ibid., vol. 2, pp. 461-476; see also table 14-2 and pp. 470-475 for an extensive discussion of "selected contrasting assumptions."
[88]Ibid., vol. 2, pp. 481-482.
[89]Ibid., vol. 2, p. 467.
[90]Ibid., vol. 2, p. 3, emphasis theirs.
[91]Ibid., vol. 2, table 14-2 and pp. 470-475; see also pp. 485-499.

- **GNP.**—Implementation of "prudent" policies to maximize export earnings, with GNP growth in the LDCs largely dependent on GNP growth in the developed regions;
- **Food.**—Major public and private investments in land development; a worldwide shift toward more fossil-fuel-intensive agricultural techniques and inputs; and (implicitly) improved resource management to protect fisheries and to prevent overgrazing, erosion, and farmland degradation;
- **Energy.**—Widespread deployment of light-water nuclear electric powerplants; implementation of more effective energy conservation programs in OECD countries; willingness of OPEC countries to meet oil demand up to their maximum production capacity; and major public and private investment in air pollution abatement so that by 1985 all countries' energy facilities are retrofitted to meet U.S. new-source performance standards for CO, SO_x, NO_x, and particulates; and
- **Technology.**—Major technological progress in almost all sectors, with no technological setbacks or adverse side effects; and extensive worldwide transfer and deployment of family-planning, yield-enhancing, nuclear-power, and pollution-abatement technologies.

In addition, the "no-policy-change" assumption itself explicitly excludes the possibility of either planned change or sudden upheaval in the world's existing political institutions and economic arrangements:

> . . . the Study assumes that there will be no major disruptions of international trade as a result of war, disturbance of the international monetary system, or political disruption. The findings of the Study do, however, point to increasing potential for international conflict and increasing stress on international financial arrangements. Should wars or a significant disturbance of the international monetary system occur, the projected trends would be altered in unpredictable ways.[92]

Findings and Conclusions of Global 2000

In the absence of more extensive policy testing, and because of the presence of contradictory and often controversial policy assumptions, Global 2000 does not provide an adequate basis for coordinated analysis or detailed policy recommendations. Furthermore, because of the omissions and inconsistencies outlined above, the study team concludes "that it is impossible to assign a high probability to any of the specific numeric projections presented" for its different sectors.[93] However, the current weaknesses and deficiencies of "the Government's global model" do not necessarily or completely invalidate its overall results, and the study team concludes that "these basic findings are qualitatively correct," since they are in general agreement with past projections by the same agencies, are supported collaterally by the alternative sectoral projections of outside organizations, and correspond "in . . . their most basic thrusts" with projections generated by "less complex but more highly integrated global models."[94]

Global 2000's often-quoted general conclusions about the future are as follows:

> If present trends continue, the world in 2000 will be more crowded, more polluted, less stable ecologically, and more vulnerable to disruption than the world we live in now. Serious stresses involving population, resources, and environment are clearly visible ahead. Despite greater material output, the world's people will be poorer in many ways than they are today.
>
> For hundreds of millions of the desperately poor, the outlook for food and other necessities of life will be no better. For many it will be worse. Barring revolutionary advances in technology, life for most people on earth will be more precarious in 2000 than it is now—unless the nations of the world act decisively to alter current trends.[95]

The principal sectoral findings on which these general conclusions are based, briefly outlined, are as follows:

- **Population.**—Global population growth rates will not decline significantly by 2000 and, in absolute terms, net population growth will be faster than it is today. The world's total population will increase by 55 percent, from 4.1 billion in 1975 to 6.35 billion in 2000, with 92 percent of the growth occurring in the LDCs, particularly in Africa and Latin America.

[92] Ibid., vol. 1, pp. 7-8.

[93] Ibid., vol. 2, p. 481.

[94] Ibid.

[95] Ibid., vol. 1, p. 1.

- **GNP.**—Worldwide GNP is projected to increase 145 percent during the 1975-2000 period, with faster annual growth in the LDCs (4.5 percent) than in the developed nations (3.3 percent), although growth rates in all regions will decline after 1985. Due to differential population growth, however, GNP per capita will grow much more slowly—an overall increase of only 53 percent worldwide, with marginal improvements or actual declines in a number of LDCs in Africa and South Asia. Existing income disparities between the richest and poorest nations will widen, and "dramatically different rates of change would be needed to reduce the gap significantly by the end of the century."[96]
- **Food.**—Worldwide food production is projected to increase by 2.2 percent annually from 1970 to 2000, a rate approximating the record increases of the Green Revolution. Since most of the good arable land is already under cultivation, most of this increase will come from more intensive use of energy-intensive inputs and technologies, resulting in an increased dependence on oil and gas and at least a doubling of real food prices by the end of the century. Since food production grows more rapidly than population, average per capita consumption will increase 15 percent worldwide by 2000, but with significant regional variations—increases of 21 percent in the developed regions but only 9 percent in the LDCs, with smaller increases in North Africa, the Middle East, and South Asia; and a "calamitous" 19.1-percent decline in Central Africa, where average caloric intake is already well below the minimum requirements set by the U.N. Food and Agriculture Organization. These projections suggest the need for food imports and food assistance will continue to grow in the developing regions, particularly in the poorest countries.
- **Energy.**—The energy projections, made in late 1977, indicate that world energy demand will increase 58 percent over the 1975-90 period. However, petroleum production capacity is not increasing as rapidly as demand, and the rate of reserve additions per unit of exploratory effort appears to be declining. As a result, technical considerations indicate that petroleum production will peak before the end of the century, although political and economic decisions by OPEC countries could cause production to level off even earlier. The resulting transition away from petroleum dependence is projected to be led by nuclear and renewable sources (primarily nuclear, but including hydro, solar, and geothermal), which are forecast to increase 226 percent by 1990; production of petroleum, natural gas, and coal is projected to increase by 58, 43, and 13 percent, respectively, over the same period. The projections also indicate considerable potential for reducing energy consumption per unit of economic production.
- **Resource prices.**—Global 2000 finds that the real prices of food, fish, lumber, water, and energy will increase significantly by 2000, with the steepest increases occurring after 1985. However, this finding shows how the nonintegrated model can lead to an economic paradox:

  > If the real prices of these commodities increase as projected, for what corresponding commodities will real prices decrease? If no compensating real-price decreases are projected, what do these "real" price increases mean theoretically—or even semantically? Unfortunately, even attempting to develop answers to these difficult questions would have exceeded the time and resource constraints of the study.[97]

- **Environment.**—Major strains will be placed on ecological systems throughout the world, leading to significant deterioration in terrestrial, aquatic, and atmospheric resources that would have adverse impacts on agricultural productivity, human mortality, and economic development. There are already signs of many of these effects, which will be felt more strongly, particularly in the LDCs, toward the end of the century. The projected increase in fossil fuel combustion could be expected to double the CO_2 content of the atmosphere by 2050, leading to a 2° to 3° C rise in temperatures and significant alterations in weather and precipitation patterns in the temperate zones,

[96] Ibid., vol 1, p. 13, compare with the discussion of UNIOWM, above.

[97] Ibid., vol. 2, p. 480 n. 1.

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where most of the world's food-exporting nations are located.

- **Species extinctions.**—Between 0.5 million and 2.0 million species of plants and animals could be extinguished by 2000, mainly through the loss of wild habitats or through pollution. This threat is particularly great in the tropical forests, which are an important potential source of new foods, pharmaceuticals, and building materials. An equally important threat is posed by the possible loss of local and wild varieties that are needed to breed pest-and disease-resistant traits into high-yield cereal grains.

Updates of these projections, developed on the basis of subsequent events or improvements in the forecasting tools, generally support the initial findings of Global 2000 and, if anything, provide even less reason for optimism:

- Fertility rates have declined more rapidly than expected in some areas, but world population in 2000 will be only 3 percent lower than originally projected.
- GNP projections are somewhat lower, due to increased petroleum prices and efforts to control inflation in OECD countries, with a consequent drop in LDC growth rates.
- Agricultural projections have also been revised downward, due to rapid increases in energy-related production costs and diminishing returns for other yield-enhancing inputs. In addition, increased concern with the consequences of intensive cultivation has led (in the United States and other developed nations) to pressure for resource-management policies that would prevent further erosion and soil deterioration. Some LDC governments are intervening in domestic markets to keep food prices low, often to the detriment of rural development and production capacity.
- The greatest differences are found in the energy sector: updated projections, reflecting the sudden large increase in oil prices in 1979, show that demand will be lower due to higher prices and slower economic growth caused by energy impacts in other sectors. Estimates of maximum OPEC production levels are lower, reflecting the cartel's resource-conservation policies. Estimates of future OECD nuclear capacity are also lower, reflecting construction delays and public concern as well as the U.S. licensing moratorium, and coal is projected to provide a larger share of energy supplies. Higher prices are also expected to encourage the adoption of alternative sources (including solar) and conservation measures.

CHAPTER 3

Findings of the Global Models

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CHAPTER 3

Findings of the Global Models

Introduction

The five global modeling studies addressed in this report demonstrate at least three fundamentally different "predictive styles"—World 3 and Global 2000 examine what might happen if present trends continue, while the Latin American and United Nations (U.N.) world models examine the goals that might be achieved through broad changes in those trends, and the World Integrated Model (WIM) examines the policies and actions that might bring those changes about.[1] The models also vary significantly in their more specific purposes, assumptions, and methodologies. In addition, they focus on different parts of the world system, at different levels of detail, and over different spans of time. These fundamental differences, as well as the more specific differences in patterns of regionalization and degrees of aggregation, make it difficult to compare their projections in any extensive or sustained manner.

The five models nevertheless display a limited consensus about the nature of the world system and the identity of the problems facing it, as well as some of the steps that might be taken to address them. The following discussion will examine the areas of general agreement or disagreement that emerge from these five studies, first in their qualitative conclusions about the general problems of the world future, and then in their quantitative findings in three key sectors: population, food, and energy. Extended technical analysis of their projections in these three key sectors and of the structural differences between the models is provided in the appendixes.

[1] See Stuart Bremer, "Testing Models," in Donella H. Meadows, John Richardson, and Gerhart Bruckmann (eds.), *Groping in the Dark: The First Decade of Global Modeling* (New York: Wiley, forthcoming), pp. 376-377.

Qualitative Conclusions About the World and Its Future

Despite the many differences between these five global models, it is possible to draw a number of common themes from them about the present state of the world and the possible paths it might follow in the future. The following statements are based on a list compiled by Donella Meadows, John Richardson, and Gerhart Bruckmann for a forthcoming review of the first decade of global modeling.[2] The statements reflect a number of qualitative findings with which (according to the authors) almost all global modelers would agree, and they are arranged in such a way as to form a loose logical argument:

- Population and physical (material) capital cannot grow indefinitely on a finite planet.
- There is, however, no reliable or complete information about the planet's ultimate carrying capacity.* There is a great deal of partial information, which optimists read optimistically and pessimists read pessimistically.
- Nevertheless, there is no known physical or technical reason why the basic human needs* of all the world's people cannot be supplied now and into the foreseeable future. These basic needs are not now being met because of political, economic, and social factors, not because of overall physical scarcities.
- Continuing "business as usual" policies over the next few decades will not lead to the best possible outcome, nor to a desirable outcome, nor even to the satisfaction of basic human needs. It would result instead in an increasing gap between the rich and the poor, worsening economic conditions, growing international tension, problems of resource availability, and environmental degradation.

[2] Meadows, Richardson, and Bruckmann, op. cit., pp. 18-19, 49-50; see also John M. Richardson, Jr., "Towards Effective Foresight in the United States Government" (prepared for the U.S. Department of State, June 1979), pp. 5-6 and app. C.

*The terms "carrying capacity" and "basic human need" are highly value-laden and therefore inescapably lead to debate.

- Because of these difficulties, the continuation of current trends is not a likely future course. Over the next three decades, therefore, the world's socioeconomic system will be in a period of transition to some new state that will be both quantitatively and qualitatively different from the present.
- The exact nature of this future state, and whether it will be better or worse than the present, is not predetermined—it is a function of decisions and changes being made now.
- Because of the momentum inherent in the world's physical and socioeconomic processes, policy changes that are made soon are likely to have more impact with less effort and cost than the same set of changes made later; and if the changes are put off for too long, they may not work at all.
- Changes in technology are expected and indeed essential: even the most optimistic scenarios might fail if technological progress is inadequate. However, no set of purely technical changes tested in any of the models was sufficient in itself to bring about a desirable outcome. The models suggest that restructuring social, economic, and political systems will also be necessary and may in fact be more effective.
- The interdependencies among peoples and nations, over time and space, are far greater than commonly imagined: actions taken at one time in one part of the world have far-reaching consequences that are often difficult to anticipate intuitively and are probably impossible to predict (totally, precisely, perhaps at all) even with computer models.
- Because of these interdependencies, isolated measures intended to reach narrowly defined short-term goals are likely to be less effective than anticipated. Decisions should therefore be made within the broadest possible context, across space and time and intellectual disciplines.
- As a further consequence of these interdependencies, cooperative, long-term approaches to achieving individual or national goals often turn out to be more beneficial to all parties than short-term, competitive approaches.
- Many existing plans, programs, and agreements—particularly complex international ones like the U.N.'s International Development Strategy—are based on assumptions about the world that are either mutually inconsistent or inconsistent with physical reality. Much time and effort have thus been spent in designing and debating policies that are in fact simply impossible.

In short, according to the authors, the modelers generally agree that the world system is going to change in the near future, and that a continuation of current trends and policies will lead to a change for the worse. They also agree that changes for the better are possible, although they disagree sharply on what those changes should be and which policies would bring them about. In the authors' words, the models indicate that "we should do something, [but] we can't be sure what we should do."[3] Environmentalism and the Club of Rome's "world problematique" (see below) seem to have influenced the earlier models, which stressed the *limits* of the present system and called for an "equilibrium state" or "organic growth." The more recent models, which stress the *inequities* of the present system and call for internal and/or international redistribution of growth and consumption, seem to have been influenced more directly by the issues surrounding the "new international economic order."

In spite of these differences in emphasis and prescription, however, general agreement does emerge about the fundamental issues or "problem nexus" for which projections must be made and solutions found.[4] The following sections, therefore, summarize projections made by the five global models in three of these crucial areas:

- **population,** which is addressed by all of the models and is the most fundamental driving variable in most of them;
- **food supply,** the most basic of human needs and the most promising basis for comparisons between the models; and
- **energy,** which reflects the more general problems of resource depletion but has a uniquely important impact on agriculture and economic activity.

[3]Meadows, Richardson, and Bruckmann, op. cit., p. 51.
[4]Bremer, op. cit., p. 375.

The purpose of these summaries is not to arrive at a "consensus projection," but rather to illustrate the similarities and differences among the models. More detailed information and technical analyses can be found in the historical survey and appendixes.

Population Projections[5]

Table 2 shows the results of a number of studies of future population growth, including three that did not employ global models. Population projections play a key role in any assessment of future world conditions, since the size of the population will determine the number of consumers of goods and services and the number of people available to produce those goods and services. In some global models, the future size of the population is projected without regard to changes in other conditions; in others, population growth projections are affected by other factors such as technology or economic development. These structural differences, combined with uncertainties about the present size and future behavior of the world's population, lead to variations in the projections themselves and differences in their reliability and usefulness to the policymaker. Reliability is also affected by time horizon, which in turn reflects one of two basic goals:

- to provide an accurate short-term (25 years or less) forecast of world conditions; or

[5]The following discussion is highly condensed; see app. A for a more detailed comparative analysis of population projections. For further information on this topic, see OTA's assessment, *World Population and Fertility Planning Technologies: The Next 20 Years*, OTA-HR-157 (Washington, D.C.: U.S. Government Printing Office, February 1982).

Table 2.—Comparison of Short- and Long-Term Population Projections

Model or source	Scenario or projection	Population in 2000 (billions)	Longer term projections
World 3	Standard run	6.0	Population increases to 7.0 billion by 2025, then decreases to 4.0 billion by 2100
	Equilibrium run	NA	Population stabilizes at 6.0 billion by 2050
World Integrated Model	Standard run	6.4	Population stabilizes at just under 7.0 billion by 2015. Death rates due to starvation are high in South Asia
Latin American World Model	Standard run	6.4	Population reaches 11.0 billion by 2040 and is still growing at 1.1 percent/yr. Death rates due to starvation rising rapidly in Asia
	Second run (improved conditions in Asia)	NA	Population reaches almost 11.0 billion by 2080 and is growing at less than 0.5 percent/yr
United Nations	1978 assessment (provisional)	5.9 to 6.5	Population reaches 8.0 to 12.0 billion by 2050 and stabilizes at 8.0 to 14.0 billion by 2150
Global 2000 (Census Bureau)	High, medium, low	5.8 to 6.5	NA
CFSC	High, medium, low	5.8 to 6.0	Population reaches 7.8 to 8.1 billion by 2050 and is virtually stationary
World Bank	Standard	6.0	Population stabilizes at 9.8 billion by 2175
Harvard	Standard	5.9	Population reaches 8.4 billion by 2075 and is virtually stationary

SOURCE: The Futures Group.

- to describe the long-term behavior of the global system.

Findings

There is relatively little variation (plus or minus about 5 percent) in the population projections for 2000, which range from a low of 5.8 billion to a high of 6.5 billion. This reflects the higher degree of certainty inherent in population projections for periods under 25 years: there is relatively little uncertainty about the number of reproductive-age females between now and 2000, although there is more uncertainty about the number of children each will bear. The global models that aim for this sort of accurate, short-term forecast (the United Nations Input-Output World Model (UNIOWM) and Global 2000) are based primarily on expert judgments about changes in fertility and mortality. As a result, population is linked to other conditions only to the extent that the experts consider the rest of the world system when they make these judgments. This short-term approach strives for accuracy and usefulness by making separate projections for individual countries, which can be summed to produce a world total.

The long-term global modeling studies (World 3, WIM, and LAWM) attempt to describe the general behavior of the entire global system over the next 50 to 125 years, and they consider population as only one of many factors in dynamic, integrated system behavior. The level of accuracy that is sufficient for this purpose is quite different from that sought in the U.N. or Census Bureau projections. However, the difficulty with this approach is that the relationships between fertility, life expectancy, and the factors that affect them—such as food production, pollution, and economic and social development—are not known, nor is the historical evidence rich enough to allow these relationships to be estimated with any degree of confidence.

As a result, long-range models are more speculative and their population projections show considerably more variation. Two differences in table 2 are particularly notable. In World 3, population actually begins to decline due to increasing death rates after 2025, and presumably would do so for Asia in WIM and LAWM if they were extended beyond 2060. All of the other projections show population growing more slowly until it reaches some stationary level. However, there are immense variations in the size of that stationary population, which ranges from a low of 8 billion to a high of 14 billion.

Limitations

The reliability of the projections, and their usefulness to the policymaker, are also influenced by a number of theoretical and data constraints and by the policy assumptions that have been built into the global models. As mentioned above, there is neither theoretical agreement nor sufficient historical evidence about the relationships between population variables and conditions in the rest of the world system. There is also considerable uncertainty in the base-year data for the initial population figures—estimates of China's population vary by as much as 14 percent, for instance, and the current population of Nigeria has been estimated at anywhere between 65 million and 85 million.

These differences in base-year estimates tend to cancel out when they are summed at the global level, and the recent round of censuses has substantially improved the information available for many countries, particularly in Africa. However, there is still uncertainty about present rates and future changes in fertility and life expectancy, resulting from at least four factors:

- uncertainty about how much birth rates have already declined;
- uncertainty about the contribution of existing family planning efforts and technologies to past declines in birth rates;
- uncertainty about how many countries will adopt family planning programs, and uncertainty about how strong or effective these efforts will be; and
- uncertainty about the relevance of past experience with family planning to those countries that have little experience with such programs, notably in Africa.

Different global models contain different assumptions about the above factors as well as about other policy decisions, all of which may have some effect on future changes in population growth. The short-range models that use exogenous popu-

lation figures also seem to assume that current trends will continue unchanged (at least until 2000), thereby excluding such disasters as international conflict and massive starvation. The long-range models, on the other hand, suggest that regional or even global disasters are increasingly likely in the longer term. World 3 and LAWM point out the dangers of inaction and delay and suggest alternatives to present trends, but neither model has adequate mechanisms for testing specific policy options. WIM, which was designed as a policy tool, is both more flexible and more disaggregated. The more detailed stand-alone projections, like those used in UNIOWM and Global 2000, can become a valuable input to further analysis for developing policy options, testing development goals, and planning broad strategies for the world future.

Agricultural Projections[6]

The world food problem has been a major concern for global modelers. All of the well-known models have one or more agricultural sectors; all consider measures of food availability to be major indices of system performance; and all indicate that the performance of the global agricultural system over the next 20 to 100 years is a matter of major concern. Table 3 compares the projections for key agricultural variables in 2000 generated by four global models and by two large-scale agricultural models, the Model of International Relations in Agriculture (MOIRA) and the Grain-Oilseed-Livestock model (GOL) used for Global 2000.

Findings

In general, the most optimistic food supply projections come from assumptions of rapid economic growth and technical progress, slow population growth, and large reserves of easily developed agricultural land. There is far greater variation in regional projections than in global projections; the most severe problems are foreseen in South Asia and Sub-Saharan Africa. The results are also highly dependent on time horizon—longer time horizons generally lead to more pessimistic findings.

All of the models except UNIOWM indicate that there will be problems in supplying food to at least some of the world's people over the next 20 years. The reason for this finding is fairly straightforward: all of the models except UNIOWM assume diminishing marginal returns to agricultural inputs and increasing costs for land development as the amount of undeveloped land decreases; in short, the models show agricultural problems because they include agricultural limits. Similarly, WIM's relatively pessimistic estimates of potentially arable land, which are 25 to 30 percent lower than the other models, undoubtedly contribute to its dire predictions of impending famine in the developing regions.

Price projections (for the models that make them) vary far more than supply projections, with

[6]The following discussion is highly condensed; see app. B for a more detailed comparative analysis of agricultural projections. For further information on this topic, see OTA's forthcoming assessment, *Impacts of Technology on Productivity of Rangelands and Croplands*, OTA-F-166 (in press).

Table 3.—Percentage Increases in Projected Global Food Production, Food Prices, and Food per Capita, 1970-2000

	World 3	World Integrated Model	Latin American World Model	U.N. Input-Output World Model	MOIRA	Global 2000 GOL Model
Food production	160	NA	NA	179[a]	85-144[b]	91-98[b]
World market price	NA	NA	NA	14	13-422[b]	30-115[b]
Global food per capita	9	NA	NA	56[a]	8-40[b]	4-26[b]

[a]Average of grain and livestock products.
[b]Reflects difference between low-growth (pessimistic) and high-growth (optimistic) scenarios.
NA—Not calculated.

SOURCE: Office of Technology Assessment

real increases ranging from 13 to 422 percent by 2000. MOIRA, which assumes that farmers will increase production to maximize their profits at a given price for agricultural inputs, concludes that measures that drive food prices up will be a successful means of reducing world hunger. However, profit maximization may be a better approximation of the behavior of rich farmers than that of poor farmers, who may not be able to borrow funds to expand production, or who may resist giving up their traditional agricultural practices. For this reason, MOIRA may overestimate the response to price incentives in the developing countries (see app. B). World 3, LAWM, and UNIOWM all lack price mechanisms, and none of the six models takes the international monetary system into account.

Technical Progress

World 3 assumes that most increases in agricultural production will come from increases in land under cultivation; Global 2000 assumes that they will come from increased yields per acre; and UNIOWM, the most optimistic of the models, assumes both increased cultivation and increased yields. All of the models except World 3 also include some form of "disembodied technological progress"—income growth not attributable to increases in capital, labor, or other inputs—which amounts to an assumption that agricultural productivity will increase automatically at no cost. The rate of such progress is 1.0 percent per year in LAWM but is unreported for the other models, despite the fact that model results are highly sensitive to its presence and magnitude. When technological progress is eliminated from LAWM, for example, Africa as well as Asia faces land constraints and economic collapse. In World 3, on the other hand, sufficiently strong assumptions about technological progress can eliminate the overshoot-and-collapse mode entirely.

Uncertainties

Population and income growth are calculated independently from food supply in MOIRA, UNIOWM, and Global 2000. The effects of pollution on agricultural yields is omitted in all of the models except World 3 and UNIOWM. These factors have an important influence on model results, as do assumptions about the availability and price of inputs such as fertilizer, irrigation, and farm machinery, but there is little agreement among the models on the values that should be assigned to them. Nor does any of the six models account for several trends that are likely to affect agriculture in the coming decades:

- regional or sectoral competition for water supplies;
- unusually bad weather, including adverse long-term climatic changes;
- Increased productivity due to advances in genetic engineering; and
- potential shrinkage or destabilization of oil and gas supplies.

Energy Projections[7]

The future availability and price of energy resources are crucial variables in long-term projections of world economic development. However, some of the models do not address energy specifically or in detail, and the findings of those that do are significantly influenced by their assumptions about the global energy system and future energy trends. In general, those models that include a finite resource stock tend to show that depletion will raise prices, slow industrial production, and dampen global economic growth. In short, as with agricultural projections, they predict energy problems because they include energy constraints.

Findings

Collectively, the models indicate that the world faces a near-term transition away from dependence on conventional sources of petroleum and

[7]The following discussion is highly condensed; see app. C for a more detailed comparative analysis of energy projections. For further information on this topic, see OTA's technical memorandum, *World Petroleum Availability 1980-2000*, OTA-TM-E-5 (Washington, D.C.: U.S. Government Printing Office, October 1980), and the OTA assessment, *Technology and Soviet Energy Availability*, OTA-ISC-153 (November 1981).

natural gas, and that the major alternatives among which future energy choices must be made are coal, nuclear, and solar power. The models whose projections extend farthest into the next century indicate that coal, conservation, and conventional nuclear power may not be enough to sustain continued economic growth. Breeder reactors, fusion, and large-scale solar power may therefore be necessary.

In World 3, rising extraction costs are the principal cause of economic collapse. As an increasing percentage of capital is allocated to obtaining nonrenewable resources, investment and productivity decline in agriculture and other sectors. New mining technologies and nuclear power can delay but cannot prevent a global economic collapse.

WIM, on the other hand, finds that collapse due to costly resources is less likely than a future based on widespread deployment of breeder reactors, but it also examines an alternative based on large "solar farms" in the deserts of the Middle East. This model is perhaps the most flexible in dealing with energy choices, and it has been used in a variety of policy tests focusing on energy prices and the behavior of both producers and consumers.

LAWM explicitly excludes the problem of energy and other resources. The authors assume that conventional fission and the potential development of fusion power will eliminate the global energy crisis without significantly raising prices.

UNIOWM, because of its restricted time horizon, foresees "[no] problem of absolute scarcity in the present century." However, the model does project a 77-percent depletion of conventional oil reserves by 2000. Its optimism about future energy supplies is based primarily on abundant coal supplies (it projects a decline in the real price of coal despite a 400-percent increase in demand) and on the assumption that nuclear power will generate an increasingly large share of the world's electricity.

Global 2000's energy projections indicate a supply-constrained oil market before 1990, with production declining thereafter. As a result, "a world transition away from petroleum dependence must take place." Global 2000 examines several potential energy systems, but foresees nuclear power and coal as the most likely alternatives. It also foresees considerable potential for "conservation-induced reductions in energy consumption."

Limitations

The accuracy and reliability of these projections are affected by their assumptions about a number of physical, technical, and economic factors:

- the total reserves of each resource;
- the rates of population and GNP growth;
- the degree to which energy demand growth will be moderated by conservation or substitution among sources;
- the bottlenecks involved in mobilizing additional or alternative energy sources; and
- potential energy breakthroughs such as fusion and solar power.

CHAPTER 4

Global Models and Government Foresight

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CHAPTER 4

Global Models and Government Foresight

Introduction

The "futures debate" of the last 15 years has taken place against a background of rapid and sometimes unexpected changes in national and world affairs, including:

- a general slowdown in the rapid economic growth that had characterized the world economy since World War II, leading to stagnation in the industrialized nations and stalled development in the less developed countries (LDCs);
- rapid population growth and urbanization in much of the Third World, leading in some cases to widespread hunger, social unrest, and political instability;
- structural changes in the world's political and economic systems, typified by the emergence of OPEC and new nuclear powers and by Third World demands for a "new international economic order;"
- growing apprehension about the cost and continued availability of natural resources, best exemplified by the energy crisis; and
- increasing concern for the regional and global environmental consequences of continued industrialization.

These and similar developments have shown that long-term global trends can have serious implications for the economic and national security interests of the United States. This in turn has led to proposals in Congress and elsewhere that the U.S. Government should improve its "foresight capability"—its institutional capacity to project long-range global trends and their consequences, and to use these projections as inputs in the process of strategic assessment, policy development, and decisionmaking. A number of Federal agencies are already using global models and other computerized models as tools of long-range analysis and planning, but the Government's present capability is limited by unevenness of data, inconsistency of assumptions, and lack of proper coordination.[1] If existing deficiencies are corrected, global models could become a more effective tool in four specific areas:

- assessing the potential future impacts of current trends, policies, and decisions;
- monitoring the national and international situation to identify early signs of potential problems or opportunities;
- formulating and evaluating a wide range of alternative policies and courses of action for achieving national goals, avoiding potential problems, and exploiting potential opportunities; and
- providing a framework to ensure consistency between short- and long-term analyses and across agency jurisdictions.

[1]For specific details, see the discussion of the *Global 2000 Study* in ch. 2 and the appendixes. Examples of previous Government uses of models and comparisons with traditional long-range analytic and planning techniques can be found in the following sources:

- *A Guide to Models in Government Planning and Operations* (Washington, D.C.: U.S. Environmental Protection Agency, 1974).
- *Federally Supported Mathematical Models: Survey and Analysis* (Washington, D.C.: National Science Foundation, 1974).
- *Computer Simulation Methods to Aid National Growth Policy*, prepared for the Subcommittee on Fisheries, Wildlife Conservation, and the Environment of the House Committee on Merchant Marine and Fisheries (Washington, D.C.: Library of Congress, Congressional Research Service, July 1975).
- *Long Range Planning*, prepared for the Subcommittee on the Environment and the Atmosphere of the House Committee on Science and Technology (Washington, D.C.: Library of Congress, Congressional Research Service, May 1976).
- Joint Economic Committee, *U.S. Economic Growth From 1976 to 1986: Prospects, Problems, and Patterns*, 12 vols. (Washington, D.C.: U.S. Congress, 1976-77), especially vol. 2, *The Factors and Processes Shaping Long-Run Economic Growth*, vol. 6, *Forecasts of Long-Run Economic Growth*, and vol. 7, *The Limits to Growth*; and
- *The Use of Models for Water Resource Management, Planning, and Policy* (Washington, D.C.: U.S. Congress, Office of Technology Assessment, forthcoming).

Benefits of Global Models

The essential claim for global models is that they represent the behavior of the real global system, or at least some of its components, in ways that are superior to the less formal mental models and forecasting techniques currently being used by decisionmakers, policy analysts, and the general public.[2] Their benefits are those of mathematical models in general and computerized models in particular, the difference being that global models are specifically designed to address problems and issues of a global scale and importance. This can make them a valuable tool of analysis and a valuable additional input to policy development and decisionmaking. Specific benefits of global models include the following.[3]

- **Longer time horizon.**—Many current forecasting techniques are used primarily for annual or short-term projections, whereas global models typically have time horizons of 20 years or more. This allows them to assess long-term effects and cumulative changes, however critical, that might not otherwise be detected.
- **Comprehensiveness.**—A computerized model can contain far more information about the world system than any single mental model. It can also keep track of many more variables and interrelations at the same time and, according to some modelers, it is far more sensitive to subtle, remote, or counterintuitive effects and outcomes.
- **Rigor.**—They impose a logical discipline by requiring the modelers—and the model users—to make explicit, precise, and complete statements of their objectives, assumptions, and procedures. The system or process being modeled must be clearly divided into its major components, and the relations between those components must be specified. This procedure may lead modelers and model users to revise their mental models—or to refine them by identifying previously ignored components and relations—even before computer analysis begins.
- **Accessibility.**—The assumptions and structure of the model must be written out before they can be run on the computer. This allows all sides to examine them, point out omissions or inconsistencies, and suggest improvements. Open communication about both the system and the model can lead in turn to the incorporation of fresh insights and differing viewpoints.
- **Logic.**—If properly designed and programed, a computerized model will draw logically correct and mathematically error-free conclusions from an extremely complicated set of assumptions and data. This can lead to novel insights into unexpected or counterintuitive system behavior, reveal areas in which further research is needed, and expose assumptions that are inconsistent or contradictory.
- **Flexibility and range.**—By making small changes in the magnitude and relations of variables, it is possible to examine the implications of a wide range of alternate assumptions and to test the sensitivity of the outcome to changes in different parameters. The models can also be tailored to "fit" particular problems, regions, or issues. The model can therefore become a powerful planning tool, and properly updated runs can be used to monitor program progress.
- **Instructiveness.**—The flexibility of global models also makes them a valuable tool for analysts, planners, and policymakers alike, allowing them to examine a broad range of possible outcomes, responses, and policy options. This can allow them to reject physically impossible options, clarify the nature of various risks, and evaluate the adequacy of different options for minimizing those risks. Thus, even when the models cannot give precise quantitative answers, they allow the users to sharpen their analytic skills and improve their intuitive "feel" for the operation of the system.

[2] L. M. Ward, et al., "World Modeling: Some Critical Foundations," *Behavioral Science*, vol. 23, No. 3, May 1978, p. 138.

[3] See Donella H. Meadows, John Richardson, and Gerhart Bruckmann (eds.), *Groping in the Dark: The First Decade of Global Modeling* (New York: Wiley, forthcoming), pp. 20-21, 42-43, 203, 310-312; and Dennis L. Little, et al., *Long-Range Planning* (Washington, D.C.: U.S. Library of Congress Congressional Research Service, 1976), prepared for the Subcommittee on the Environment and the Atmosphere of the House Committee on Science and Technology, pp. 456-457.

Limitations of Global Models

Despite these benefits, global models remain subject to a number of limitations that may constrain their accuracy, reliability, and usefulness for policymaking:[4]

- **Theoretical limitations.**—The structures of different global models are based on underlying assumptions adapted from systems analysis and several other disciplines, including engineering, economics, and the natural sciences. There is no general agreement on the relative validity of their competing explanations of socioeconomic phenomena, nor is there any evidence that one approach produces results that are consistently more reliable than the others. In addition, theoretical understanding of a number of important processes (for example, the effect of socioeconomic conditions on fertility rates) is too weak to allow adequate modeling, although projections based on alternative assumptions can still be useful and instructive.
- **Methodological limitations.**—The essence of modeling is a simplification that improves understanding, but this means that a limited number of discrete factors and relations must be used to describe the dynamic complexity and ambiguity of the real world. Theoretical bias and data constraints often determine which variables and relations are included or omitted, but no model could include every factor without becoming as complicated as the real world.
- **Data limitations.**—Data vital to proper forecasting are often nonexistent, inaccessible, or unreliable. This is particularly true for environmental data and for most data on the LDCs. This situation has improved somewhat in recent years, but data limitations remain a serious constraint on reliability and on the sectoral and regional coverage that models can achieve. In some cases there are inadequate empirical data on which to base improvements in theoretical understanding.
- **Practical limitations.**—An effective global modeling effort requires considerable time, an interdisciplinary team of modelers and technicians, a large and continuously updated data base, access to computers of sufficient capacity, support services, and money. Skimping on any of these requirements greatly increases the risk of error and unreliability in the resulting forecasts.

[4]See Meadows, Richardson, and Bruckmann, op. cit., pp. 22, 43-44, 312-313; Little, et al., op. cit., pp. 458-459; Ward, et al., op. cit.; and *The Global 2000 Report to the President*, vol. 2, ch. 14.

Institutional Opportunities and Barriers

Since President Theodore Roosevelt created the National Conservation Commission in 1908, numerous presidential and congressional committees, commissions, task forces, and studies have recommended in one way or another that the U.S. Government should improve and/or institutionalize its long-range analysis, planning, and policymaking capability. The most recent study discussed in this report, *The Global 2000 Report*, reveals that, individually, the executive agencies possess an impressive, if uneven, capability for long-range analysis and forecasting within their separate areas of responsibility and interest; but it also reveals "that, collectively, the executive agencies of the government are currently incapable of presenting the President with a mutually consistent set of projections of world trends in population, resources, and the environment."[5] Nevertheless, according to the report, "Important decisions—involving billion-dollar federal programs and even the national security—are partially based on these projections," which "have generally been used by the government and others as though they had been calculated on a mutually consistent basis."[6]

[5]*The Global 2000 Report to the President*, vol. 2, p. 3.
[6]Ibid., vol. 2, p. 454.

The interagency followup report, *Global Future: Time to Act*, carries these conclusions a step further:

> If there is one clear lesson from the exercise of putting the *Global 2000 Report* together, it is that the U.S. government currently lacks the capacity to anticipate and respond effectively to these global issues. . . . As of today, the government still does not adequately: 1) project and evaluate future trends; 2) take global population, resource, and environmental considerations into account in its programs and decisionmaking; and 3) work with other countries to solve these problems.[7]

The deficiencies in the Government's current foresight capability appear to be institutional rather than technical. In a recent analysis of the potential Government policy applications of computer models, A. D. Little found modeling to be potentially quite useful:

> Current state-of-the-art techniques in long-range forecasting of population, resources, and the environment present significant opportunities for the State Department to enhance its capabilities for analysis of the long-run future socioeconomic and political consequences of foreign national demographic, resource, and environmental conditions.[8]

After considering the various limitations of computerized modeling (see above), the A. D. Little report concludes that "Institutional conditions are often much more of a constraint to the effective use of forecasting models than methodological or data considerations."[9] These findings, although addressed to the Department of State, would appear to be equally relevant to the modeling activities of other agencies and of the Government as a whole.

The *Global 2000 Report* includes similar findings—the discrepancies and lack of integration among its forecasts arise:

> . . . essentially because of the institutional context in which the elements of the model were developed and are being used. This context emphasizes sectoral concerns at the expense of interactions among the sectors and leads to distorted and mutually inconsistent projections.[10]

* * *

This design is no institutional accident but is in conformity with the bureaucratic division of responsibility within the executive agencies [and within the committee structure of the U.S. Congress]. . . . Furthermore, in the absence of ongoing institutional incentives to address cross-sectional interactions, the present form of the government's global model is not likely to change significantly in the foreseeable future.[11]

* * *

Moreover, it would be naive not to recognize that projections and the procedures used to produce them have frequently been criticized by Congressional committees and others as subject to influences not purely analytical in origin. Each agency has its own responsibilities and interests, its own constituencies, and its own pet projects. Often, an agency finds it helpful to use advanced analytic techniques (and associated projections) as weapons in the adversary process of initiating, justifying, and defending its programs. As a result, there have been many occasions in which the elements (and associated projections) of the government's global model have been used in support of (or in opposition to) highly controversial programs, and the credibility of the projections has become a subject for debate. This has been especially true in recent times, as both the issues and the advanced analytic procedures used for examining the issues have become increasingly complex and, in a sense, incomprehensible to many nonexperts.[12]

Another analysis of the Government's current foresight capability points to these and similar institutional barriers. The following list of major obstacles presents 10 frequently cited reasons for the Government's failure to correct the perceived deficiences in its existing foresight capability.[13]

1. There is little or no top-level support for foresight.
2. The "best talent" has never worked on broad, long-term issues.
3. Bureaucratic rigidity, compartmentalization, and specialization have frustrated attempts to promote cooperation among departments and to take a broad, long-term view.
4. Time pressures restrict vision to the short run.

[7] Nicholas Yost, staff director, *Global Future: Time to Act, Report to the President on Global Resources, Environment and Population* (Washington, D.C.: U.S. Council on Environmental Quality and Department of State, January 1981), p. 206.
[8] Arthur D. Little, Inc., op. cit., pp. ix-x.
[9] Ibid., p. xii.
[10] *The Global 2000 Report to the President*, vol. 2, p. 454.
[11] Ibid., vol. 2, p. 461 and footnote.
[12] Ibid., vol. 2, pp. 478-480.
[13] John M. Richardson, Jr., "Towards Effective Foresight in the United States Government" (prepared for the U.S. Department of State, June 1979), pp. 13-18.

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5. By the time models or forecasts are developed, policy-level officials have either moved on or lost interest.
6. Policy-level officials lack the knowledge and experience to properly use models.
7. The products of modelers' efforts are incomprehensible or irrelevant [to practical policy issues], or both.
8. There is poor communication among those who contract for models and forecasts, those who develop them, and those who are supposed to use them.
9. Congress doesn't care about the long-term future.
10. The public doesn't care about the long-term future.

CHAPTER 5

Priorities and Strategies for Improving U.S. Government Foresight

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CHAPTER 5

Priorities and Strategies for Improving U.S. Government Foresight

Introduction

Numerous proposals for improving Government foresight have been put forward, both in the past and in response to the *Global 2000 Report*.[1] Some have been modest and limited, others sweeping; some would require major legislation from Congress, while others could be encouraged through oversight or carried out through executive order or agency initiative. The following discussion presents the most frequent and representative proposals, which generally reflect four fundamental priorities:

- correct the existing deficiencies in Government models, as identified by Global 2000 and other assessments;
- coordinate the Government's current predictive capability and activities;
- support technical improvements in the current capability and advance the state of the art; and
- link the Government's foresight capability with its policymaking and management activities.

These priorities and the various strategies for carrying them out do not represent "options" in the normal sense of the term. They are complementary and mutually reinforcing parts of a larger, integrated effort to make the Government's foresight capabilities more reliable, more coordinated, and more useful to both analysts and policymakers.

[1]See especially Dennis L. Little, et al., *Long-Range Planning* (Washington, D.C.: U.S. Library of Congress Congressional Research Service, 1976), prepared for the Subcommittee on the Environment and the Atmosphere of the House Committee on Science and Technology, pp. 384-390; John M. Richardson, Jr., "Towards Effective Foresight in the United States Government" (prepared for the U.S. Department of State, June 1979), pp. 5-6 and app. C; Arthur D. Little, Inc., *Long-Range Forecasting Models of Population, Natural Resources, and the Environment: Their Use in Foreign Policy Assessment at the National Level* (prepared for the U.S. Department of State, Nov. 1979), pp. II.2-3; and *Global Future: Time to Act*.

ACTION 1.—Correct the Existing Deficiencies Identified by Global 2000 and Other Assessments

Global 2000's authors, reviewers, and critics have identified numerous deficiencies in each of its component submodels, many of which are noted in chapter 2 and the appendixes to this report. The followup report by the interagency Task Group on Data and Modeling Capability identified the correction of these existing deficiencies as the first priority in improving the Government's ability to analyze and address global problems.[2] This action could be taken as a matter of course by individual agencies, many of which are already planning or carrying out evaluations and modifications of their present capabilities. However, such actions might be given higher priority, higher level attention, and greater coherence by the agencies if they were encouraged by a presidential directive and/or congressional oversight.

The Department of Energy's (DOE) Energy Information Agency has institutionalized this evaluative function in its Office of Energy and Information Validation, which might provide a model for other agencies. Another possible strategy for carrying out this priority would be the creation of high-level advisory committees within each of the relevant agencies. The functions of these agency advisory committees might include the following:

[2]"Report of the Global 2000 Task Group on Data and Modeling Capability," prepared for the President's Task Force on Global Resources and Environment, Nov. 7, 1980.

- prepare an inventory of existing models and data bases, including the purposes for which they were originally developed and the uses to which they are currently put, with particular attention to their scope, complexity, and assumptions;
- identify existing deficiencies and evaluate any plans to modify existing models or obtain new models, preferably through independent assessment by outsiders;
- evaluate current and potential applications of models and projections by agency analysts, planners, and policymakers, with particular attention to the specific information needs of potential users;
- encourage expanded use of models and projections through educational and training programs for agency personnel;
- improve communication between those who use models and those who develop or maintain them, with particular attention to increasing the relevance and responsiveness of model outputs to the needs of potential users; and
- identify likely future problems and issues within the agency's area of responsibility and interest, with the goal of developing problem-oriented and policy-relevant models and data bases.

ACTION 2.—Coordinate the Government's Current Modeling Capabilities and Activities

While the creation of agency advisory committees might be a useful and necessary foundation for improving the Government's foresight capability, it fails to address the equally important problem of linking and coordinating these agency capabilities, which currently focus on relatively narrow, mission-oriented sectoral concerns. Problem-oriented models would most appropriately be developed by the agencies that would use them, but overall analysis and policymaking would require consistent, integrated forecasts that incorporate data and projections from several agencies. Global 2000 shows that it is in this area that current Government efforts have been most unsuccessful: the delays in completing the study itself were caused in part by problems involving computer compatibility and tape transfer.

The simplest strategy for carrying out this action would be a process of interagency negotiation and arbitration to bring about greater consistency and compatibility between the separate agencies' data bases, assumptions, and projections. Ultimately, however, the effectiveness of such a process might require the creation of an interagency task force to provide a focal point and to resolve conflicts. The coordinating functions of such a task force might include the following:

- prepare an inventory of models and data bases currently maintained by individual agencies (including their respective strengths and weaknesses), and identify any areas of compatibility, overlap, or redundancy;
- identify gaps, sources of inconsistency, and points of conflict among existing agency capabilities and suggest possible solutions;
- promote greater understanding, communication, and technical cooperation among agencies (simply getting the Government's modelers together was one of the Global 2000 study's major accomplishments);
- review and coordinate agency plans to modify or obtain new models or data bases, in order to prevent redundancy, ensure greater compatibility, and identify software or hardware needs;
- develop consistent procedures and protocols for data collection, standards of reliability, and validation, as well as for model documentation and validation;
- establish a central clearinghouse to provide information on the location of models and data bases and to permit easier access, exchange, and integration of data, assumptions, and projections;

- identify key future problems and issues, designate lead agencies to gather information and monitor trends in each area, and ensure the publication of timely projections; and
- link existing models, such as the World Integrated Model (WIM) maintained by the Joint Chiefs of Staff and other agencies, the Grain-Oilseed-Livestock model maintained by the Department of Agriculture, and the IEES/LEAP models maintained by DOE.

ACTION 3.—Support Technical Improvements in the Current Capability and Advance the State of the Art

Technical coordination among agencies and between the executive and legislative branches would eventually require some form of third-party mediation. Creation of an institutional mechanism for this purpose would also present an opportunity for carrying out research and development aimed at technical improvements in existing agency capabilities, the Government's capability as a whole, and the state of the art in global modeling generally. To carry out these functions, however, this institutional mechanism would have to be insulated from the day-to-day concerns of the line agencies and, thus, able to take a long-term view and incorporate broader and more diverse perspectives. Because its mission would be only indirectly linked to policy-related concerns, however, it would seem that such an organization should be created only in conjunction with other initiatives that are directly relevant to policy development and coordination (see action 4). Technical improvements are nevertheless a necessary prelude to policy applications.

Several strategies have been suggested for carrying out this priority. In the short term, an ad hoc commission or research advisory panel might be appointed to identify key technical problems and establish research priorities. To be effective, however, such an effort would have to be both open and ongoing. A frequently encountered proposal for the long term is the creation of a "hybrid" or "quasi-public" institute devoted to long-range analysis, global modeling, and futures research. The primary goal of such an institute would be to encourage private-sector understanding of, support for, and participation in Government foresight activities. Specific functions might include the following:

- solicit the thoughts and enlist the creative talents of the private sector, particularly the business and educational communities, to "cross-fertilize" Government ideas and initiatives;
- support research by nongovernmental organizations to create and/or improve global models and other analytic tools, especially those based on paradigms other than economics;
- encourage impartial, third-party validation and assessment of existing or proposed Government models;
- establish a "global modeling forum," patterned on the Energy Modeling Forum, at which modelers could exchange ideas and critique one another's work;
- assess work done outside the Government or outside the United States and, where appropriate, suggest its incorporation into the Government's capability;
- support data-gathering efforts and the development of needed data-gathering technologies and systems; and
- establish and maintain communication with similar organizations in other countries through such organizations as the International Institute of Applied Systems Analysis.

ACTION 4.—Link the Government's Foresight Capability With Its Policymaking and Management Activities

The above-described institute, although it could help to broaden the dialog on global problems and advance the state of the art in global modeling, could not by itself ensure that these concerns would be translated into coordinated Federal policy. If the U.S. Government is at present giving insufficient attention to long-range global problems, it could be in part because no single agency has the mandate or the ability to look at these problems on an integrated, ongoing basis. A final priority, therefore, might be to create an institutional focus that could coordinate the various elements of the Government's foresight capability and ensure that long-range global concerns and national priorities are routinely taken into consideration in the formulation, selection, and implementation of U.S. policy at all levels.

In Congress, this would require continuing efforts to ensure that legislative proposals are evaluated in terms of their long-term global impacts and implications. One rationale for such evaluation might be provided by House Rule X, which directs in part that each standing committee (other than Budget and Appropriations):

> . . . shall review and study any conditions or circumstances which may indicate the necessity or desirability of enacting new legislation within the jurisdiction of that committee . . . and shall on a continuing basis undertake futures research and forecasting on matters within the jurisdiction of that committee (2(b)(1)).

The long-range analytic capabilities of the legislative support agencies might also be coordinated and brought to bear on such issues. In addition, Congress might also encourage appropriate initiatives in the executive branch through oversight hearings, personal appeals, or directed research. For example, several committees have already held or plan to hold hearings on long-range demographic issues, Global 2000, and Government foresight. In addition, Sen. Charles McC. Mathias has written a letter to the President, cosigned by 84 other Members, strongly urging that he give the *Global Future: Time to Act* report his thoughtful consideration and that he "put into motion the machinery that will translate these recommendations into action."[3] Another example is the request by the Technology Assessment Board for this OTA study.

Proposals for creating an institutional focus for long-range global policymaking in the executive branch usually suggest that—to ensure support from and access to high-level decisionmakers—it should be located in the Executive Office of the President (EOP). The current administration has

[3]Sen. Charles McC. Mathias, letter to the President, June 22, 1981. This letter, initiated by Senator Mathias and sponsored by Senator Dodd and Representatives Udall, Conte, and Schneider, was signed by the following Members of the House and Senate:

Sen. Charles McC. Mathias, Jr.
Sen. Christopher J. Dodd
Rep. Morris K. Udall
Rep. Silvio O. Conte
Rep. Claudine C. Schneider
Sen. Charles H. Percy
Sen. Mark O. Hatfield
Sen. Alan Cranston
Sen. Dale Bumpers
Sen. Claiborne Pell
Sen. Lowell Weicker
Sen. Carl Levin
Sen. George Mitchell
Sen. Robert Stafford
Sen. Paul Tsongas
Sen. Harrison Williams
Sen. Paul S. Sarbanes
Sen. Thomas F. Eagleton
Sen. Edward M. Kennedy
Sen. Spark M. Matsunaga
Sen. John C. Danforth
Sen. Daniel K. Inouye
Sen. William C. Cohen
Rep. Barney Frank
Rep. James H. Scheuer
Rep. Timothy E. Wirth
Rep. Sam Gejdenson
Rep. Richard A. Gephardt
Rep. John Conyers, Jr.
Rep. Paul McCloskey
Sen. Don Riegle
Sen. John H. Chaffee
Sen. Max Baucus
Sen. Walter D. Huddleston
Sen. Dan Quayle
Rep. Millicent Fenwick
Rep. Gerry E. Studds
Rep. Wyche Fowler, Jr.
Rep. Albert Gore, Jr.
Rep. Anthony C. Beilenson
Rep. Baltasar Corrada
Rep. Anthony Toby Moffett
Rep. Edwin B. Forsythe
Rep. Howard Wolpe
Rep. Jerry M. Patterson
Rep. Harold C. Hollenbeck
Rep. Stephen J. Solarz
Rep. Mike Lowry
Rep. M. Caldwell Butler
Rep. Barbara A. Mikulski
Rep. Bill Frenzel
Rep. Fortney H. Stark
Rep. Thomas A. Daschle
Rep. Lawrence J. DeNardis
Rep. Frank Horton
Rep. Leon E. Panetta
Rep. Claude Pepper
Rep. Bruce F. Vento
Rep. Cooper Evans
Rep. Les AuCoin
Rep. Berkeley Bedell
Rep. John LaFalce
Rep. James M. Jeffords
Rep. Vic Fazio
Rep. Richard L. Ottinger
Rep. Donald Pease
Rep. George E. Brown, Jr.
Rep. Thomas J. Tauke
Rep. Jonathan B. Bingham
Rep. Matthew F. McHugh
Rep. Patricia Schroeder
Rep. James Weaver
Rep. Bob Edgar
Rep. William R. Ratchford
Rep. Ron Wyden
Rep. Norman Y. Mineta
Rep. Nicholas Mavroules
Rep. Dante B. Fascell
Rep. William Lehman
Rep. Philip R. Sharp
Rep. James L. Oberstar
Rep. Charles E. Schumer
Rep. Edward J. Markey
Rep. Shirley Chisholm
Rep. George W. Crockett, Jr.

apparently taken a step in this direction by creating a new "national indicator system" directed by a special assistant to the President. He describes the project as "a system for providing social and demographic information to the policy people in a systematic and regular way, in advance of policy debates," in order to give high-level policymakers "a view of [the] changing world" and a sense of how "everything has its cross-impacts on everything else in society."[4] The system, which will lead to twice-monthly briefings for the President, Vice-President, Cabinet, and senior EOP staff, will focus primarily on national trends but will also examine international trends if there is an obvious connection or a special request from the "long-range policy group" that previews the briefings.

Other proposals for structuring and housing an EOP foresight capability have included the following options:

- **Create a new office in EOP devoted exclusively to long-range global issues.**—Such an entity would give the issues greatest emphasis, ensure access to the President, avoid competing responsibilities, and facilitate coordination of agency capabilities and activities.
- **Assign responsibility for these issues to an existing EOP office.**—This would avoid the need to create a new EOP unit. Several existing offices (e.g., the Office of Management and Budget, National Security Council, or Council on Environmental Quality (CEQ)) have analogous or complementary missions and expertise, and CEQ has already begun planning a followup to the Global 2000 study. Additional staff and resources would have to be made available, and there is a possibility that long-range global issues might not receive full attention because of the unit's existing functions and responsibilities.
- **Create an interagency coordinating committee on long-range global issues.**—Such a committee might be chaired by the Vice President (in conjunction with his current duties as chairman of the Crisis Management Team) or by the head of an existing EOP unit, but even with a staff of its own it would probably be less efficient and less effective than a dedicated office.
- **Assign responsibility for policy development on long-range global issues to a Special Assistant to the President.**—Such an individual, with the help of a small staff, could have access to the President and could ensure a somewhat better degree of interagency coordination, but this office would have to depend, in turn, on modeling and analytic expertise from other sources.

The functions and objectives that have been suggested for this new EOP office include the initiation, supervision, and coordination of all of the functions outlined for the preceding priorities, plus the following:

- ensure that the President and other top-level decisionmakers are presented with the best possible analyses and broadest possible range of policy options on long-range global issues;
- use global models (in combination with other analytic techniques) to determine the effect of various agency goals and budget items on long-range global trends and strategic interests;
- encourage an open and vigorous national dialogue on long-range global problems and issues, with the goal of developing a clear definition of U.S. national goals and strategic interests in these areas;
- prepare a "policy statement on the future," to be presented by the President, as a means of focusing attention and forcing action on long-range global issues;
- issue periodic reports, similar to an executive agency's annual report to Congress, on major global issues and, at longer intervals, conduct comprehensive, integrated studies of long-range global trends and problems;
- issue periodic reports on the state of the art in global modeling and the state of the Government's foresight capability; and
- in conjunction with the Department of State, encourage similar assessments of long-range issues by foreign governments and cooperate in the data-gathering and analytic activities of the various international organizations.

[4]Richard Beal, Special Assistant to the President and director of planning and evaluation; quoted by Philip J. Hilts, "White House Uses Social Sciences But Cuts Funding for Research," *Washington Post*, June 29, 1981, p. A8.

Appendixes

APPENDIX A

Population Projections[1]

Introduction

Population projections play a key role in any assessment of future world conditions, since the size of the population determines the number of consumers of goods and services and the number of people available to produce those goods and services. The rate and distribution of population growth will also determine the short-term strains that are put on the world's socioeconomic system, just as the ultimate size of population will determine the long-term strains that are put on the planet's physical and biological systems. Three of the global models—World 3, World Integrated Model (WIM), and Latin American World Model (LAWM)—try to describe the general long-term behavior of all components of the global system, including population. In these models, the determinants of population change—fertility and life expectancy—are linked to other sectors through feedback loops that simulate the effect of changing physical and socioeconomic conditions on the rate of population growth. The other models try to provide a detailed, short-term prediction of world conditions; in these models the future size of the population is projected in a more straightforward way, unrelated to the projection of other conditions.

These differences in purpose and technique, combined with differences in time horizon and the uncertainties surrounding the present size and future behavior of the world's population, lead to variations in the projections themselves and in their relative reliability. The projections are also influenced by policy assumptions and by the models' degree and pattern of geographical regionalization. All of these factors affect the usefulness of the models and projects for the policymaker.

Purposes, Structures, and Projections

World 3

This highly aggregated global model was designed to display the long-term interactions among major world systems—population, nonrenewable resources, capital, agriculture, and pollution—in order to investigate the consequences of five major trends at the global level: accelerating industrialization, rapid population growth, widespread malnutrition, depletion of nonrenewable resources, and environmental deterioration. In order to examine the long-term effects of these trends, the model was designed to simulate interactions over a 200-year period, from 1900 to 2100. The system dynamics modeling technique is particularly useful for simulating two important kinds of system behavior—feedback and delays—and is thus a powerful tool for understanding complex system behavior. This makes it a suitable approach for exploring the general shape of long-term global system behavior, but it is generally less useful than other techniques for producing accurate short-term forecasts of individual variables.

The population sector of World 3 is highly aggregated: it has only one geographic region and only four different age groupings: 0 to 14, 15 to 44, 45 to 64, and over 64. Global population is determined solely by the effects of changes in birth rates and death rates, but the determination of these rates depends heavily on interaction with the rest of the model. The death rate is calculated from average world life expectancy, which in turn is determined by four influences that the authors, based on historical evidence and expert judgment, postulate in the following relationships:

- Life expectancy increases with increasing food availability, reaching a maximum when food per capita is about four times the present world average.
- Life expectancy increases with increasing health services per capita, although with about a 20-year delay.
- Life expectancy initially increases with crowding because of increased industrialization and urban services, but beyond a certain level crowding has a negative influence on life expectancy due to the effect of local pollution and stress-related diseases.
- Life expectancy decreases as the amount of persistent pollution increases.

These relationships are intended to capture the general direction and magnitude of the four influences on life expectancy. Although exact equations must be entered into the model, these equations are not meant to be rigorous quantifications of the actual relationships.

The birth rate is calculated from the fertility rate, which in turn is influenced by two factors: desired fertility, and fertility-control effectiveness. Fertility-control effectiveness is expressed as a function of level of development, as measured by industrial output per capita, and reaches 100 percent at a level of development three times higher than the current average world level. Desired family size is assumed to be affected by two further influences—the social norm and the individual response

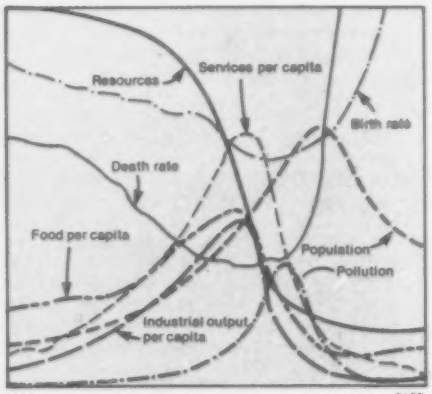
[1]The following material is based on an OTA working paper prepared by J. Stover of the Futures Group, Glastonbury, Conn. For further information on this subject, see OTA's assessment, *World Population and Fertility-Planning Technologies: The Next 20 Years*, OTA-HR-157, February 1982.

to the social norm—in such a way that desired family size ranges from a high of 5 children when income is low to a low of 1.5 children when income is high. As with life expectancy, however, the specification of these relationships is based on expert judgments aided by the small amount of available historical evidence.

The entire World 3 model was calibrated by simulating the period from 1900 to 1970, during which period the model correctly represents the broad dynamics of world population.

In the standard run of the World 3 model, world population increases to about 6 billion by 2000 and reaches a maximum level of about 7 billion by 2025, but then declines rapidly to only 4 billion by 2100 (see fig. A-1). This decline occurs because resource depletion causes an increasing fraction of capital to be used in extracting raw materials, thereby reducing the amount available for other investments, especially agricultural production. As investment in agriculture lags, food per capita begins to decline, causing a higher death rate, a decline in life expectancy, and ultimately a decline in population. This model run is meant to represent the most likely mode of system behavior if there is no change in past trends and policies, and the authors argue that it demonstrates the need for action to ensure that such a result does not occur.

Figure A-1.—World 3 Standard Run



The "standard" world model run assumes no major change in the physical, economic, or social relationships that have historically governed the development of the world system. All variables plotted here follow historical values from 1900 to 1970. Food, industrial output, and population grow exponentially until the rapidly diminishing resource base forces a slowdown in industrial growth. Because of natural delays in the system, both population and pollution continue to increase for some time after the peak of industrialization. Population growth is finally halted by a rise in the death rate due to decreased food and medical services.

SOURCE: *Limits to Growth.*

In a series of sensitivity and policy tests, the authors show that neither increased resources nor improved technologies have any significant effect on this basic behavior mode: population invariably peaks before 2050 and declines thereafter, although the maximum population varies from 7 billion to 9 billion and the population in 2100 varies from 3 billion to 5 billion. The reasons for the collapse do change, however: for example, when the resource limits to growth are removed, increases in pollution become the factor that eventually causes the death rate to increase.

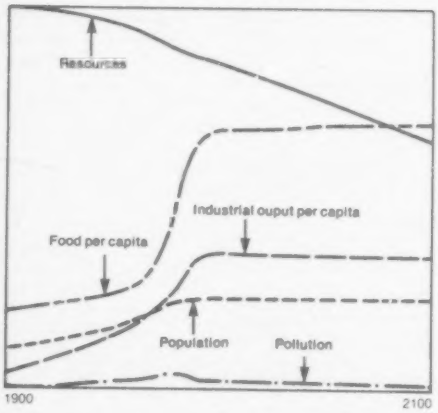
Only two scenarios were able to avoid the basic pattern of overshoot and collapse. In the first, based on the highly unrealistic condition of removing *all* the physical limits to growth, population continued to grow and reaches about 14 billion by 2100. The second is the "global equilibrium" scenario, based on an integrated set of policies designed to bring about a gradual transition to a stable, nongrowth world (fig. A-2). These policy changes, all of which are implemented beginning in 1975, include the availability of "perfectly effective" birth control and a worldwide reduction of desired family size to 2 children. Under these conditions, the population grows to only 5 billion by 2000 and stabilizes at around 6 billion by 2050. If the needed policy changes are delayed until 2000, however, the equilibrium state is not sustainable (fig. A-3).

The usefulness of this model to policymakers lies mainly in pointing out the potential dangers ahead, the costs of delaying action, and the need for considering the whole system when thinking about one aspect of the problem. However, since the model does not contain adequate policy levers (i.e., policymakers cannot directly control the variables in the model), its usefulness for policy testing and evaluation is limited.

World Integrated Model (WIM)

This global model, the first of several to be built in response to what many saw as the inadequacies of World 3, differs from the latter in one major aspect—disaggregation. WIM represents a world composed of many different subsystems that interact with one another hierarchically on five different planes or strata: individual, group, demographic-economic, technological, and environmental. It also divides the world into 10 or more geographic regions; each region is a complete model in itself, but interacts with the other regions through international trade. The model is not an explicit system

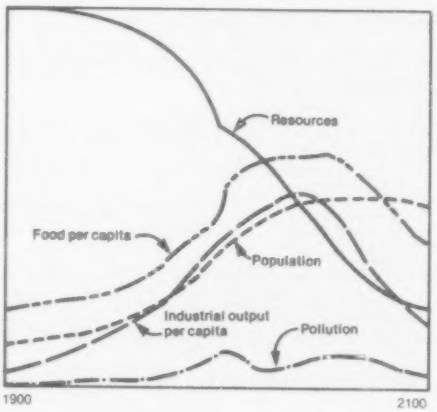
Figure A-2.—World 3 Equilibrium Run



Technological policies and growth-regulating policies produce an equilibrium state sustainable far into the future. Technological policies include resource recycling, pollution control devices, increased lifetime of all forms of capital, and methods to restore eroded and infertile soil. Value changes include increased emphasis on food and services rather than on industrial production. Births are set equal to deaths and industrial capital investment equal to capital depreciation. Equilibrium value of industrial output per capita is three times the 1970 world average.

SOURCE: *Limits to Growth.*

Figure A-3.—World 3 Run With Stabilizing Policies Introduced in the Year 2000



If all the policies instituted in 1975 in the previous figure are delayed until the year 2000, the equilibrium state is no longer sustainable. Population and industrial capital reach levels high enough to create food and resource shortages before the year 2100.

SOURCE: *Limits to Growth.*

dynamics model, but it does incorporate some of the feedback relationships and delays that are contained in World 3, as well as many new ones.

The population sector of each region divides the population into 85 1-year age cohorts. Fertility is determined by the level of socioeconomic development in each region, including both the reduction in desired family size and the increased effectiveness of contraceptive use. Increasing levels of education also lead to declining fertility.

Mortality is also linked to the rest of the model. Life expectancy increases with increasing level of development and (in some versions of the model) it is also affected by food availability: the model calculates the amount of calories and protein available in each region, and when these amounts fall below sufficient levels, additional deaths due to starvation result. All of these relationships are judgmentally determined—as in World 3, they are meant to capture the general shape of the real-world relationships, without attempting to quantify them rigorously.

The standard run of the model shows the result of continuing historical patterns of development. In this run, however, the relationships between education, development, and fertility are replaced by the "optimistic though reasonable" assumption that successful population policies will cause fertility rates in all regions to drop to the replacement level (i.e., births equal deaths) within 35 years. The authors did this in order to "avoid biases that might be introduced by the predominance of population growth factors."[2] This standard run shows world population increasing from 4 billion in 1975 to about 6.4 billion by 2000 and stabilizing at about 6.8 billion by 2015.

In other runs the authors have examined the effects on world population of delays in starting a worldwide policy to achieve replacement fertility rates. Assuming that it takes 35 years from the start of such an effort until replacement level fertility is reached, they found that world population would stabilize at about 7 billion if the effort is started in 1975, 10 billion if it is started in 1985, and 12 billion if it is started in 1995.

Because of the differences in regional detail, the conclusions of the WIM study are different from those of

[2]M. D. Mesarovic and E. Pestel, *Mankind at the Turning Point* (New York: Dutton, 1974), p. 57.

World 3. The authors conclude that worldwide collapse is not likely to result even if past trends continue, but that catastrophes could well occur at the regional level well before 2050. These regional collapses, occurring at different times and for different reasons, will nevertheless profoundly affect the entire global system. The solution to this problem lies not in stopping all growth but rather in achieving what the authors call "organic growth"—i.e., different kinds of growth in different regions, such as continued industrial growth in the LDCs but service-oriented growth in the developed countries. Without early action to ensure a transition to this kind of balanced, differentiated growth, the authors say that regional and finally global disaster is inevitable.

The model was designed to be employed by policymakers. Extensive work has gone into making the model interactive so that policymakers can experiment with it and, thereby, increase their understanding of the future effects of current policy decisions. Since the original model is not disaggregated to the country level, policymakers cannot see the effect of specific policies that they might implement in their own countries. However, subregional and country models based on the same concepts have been developed by former members of the modeling team in response to the needs of specific clients.

Latin American World Model (LAWM)

This model was also constructed in response to limitations seen in the World 3 model, and in particular to its disturbing implications for the developing world. If economic growth must stop soon in order to avert world collapse, what hope do the poor countries have of ever alleviating their poverty? The Latin American authors of this study concluded that the proper question to ask is: "What changes in the structure of the present socioeconomic system would be required in order to bring about a better life for all?"

Since the model attempts to answer a different question, its modeling technique is also different. LAWM is based on optimization techniques, and the model is structured in such a way as to determine the allocation of labor and capital that will ultimately maximize life expectancy—its measure of the satisfaction of basic human needs. The model divides the world into four regions—the developed countries, Latin America, Africa, and Asia—each of which functions more or less independently. The model does contain some physical constraints, but its structure reflects a general underlying assumption that physical limits to growth will not be as important as social and political limits. As a result, its projections do not reflect how the world *will* be, but rather how it *could* be if the indicated allocation policies were followed.

The population sector of LAWM, which is designed to identify the social and economic factors that influence population growth and life expectancy, is both more detailed and more complicated than those of World 3 and WIM. The complex web of variables and influences (shown in fig. A-4) can, however, be reduced to a single, fairly straightforward hypothesis: "The only truly adequate way of controlling population growth is by improving basic living conditions."[3] Thus, the allocation of capital and labor to any of the basic needs sectors—food, education, housing, and other consumer goods and services—will result in lower birth rates and/or higher life expectancy. These influences are in fact compounded, since lower birth rates lead to higher life expectancy, which in turn leads to a further decrease in birth rates.

Education and agriculture seem to have been given particular weight in LAWM, but all of the relations were estimated through descriptive analysis, using scattered data and rather esoteric mathematical techniques, and they should not be confused with causal relationships, although the formulation of the model implicitly assumes them to be causal.[4] The correlations between estimated and actual birth rate and life expectancy for the test period (1960-70) are very high (+0.90 and +0.95, respectively), but this technique gives no indication of whether or not the postulated functions are correct. If demographic change in the real world follows different rules, this optimization procedure will not generate reliable projections.

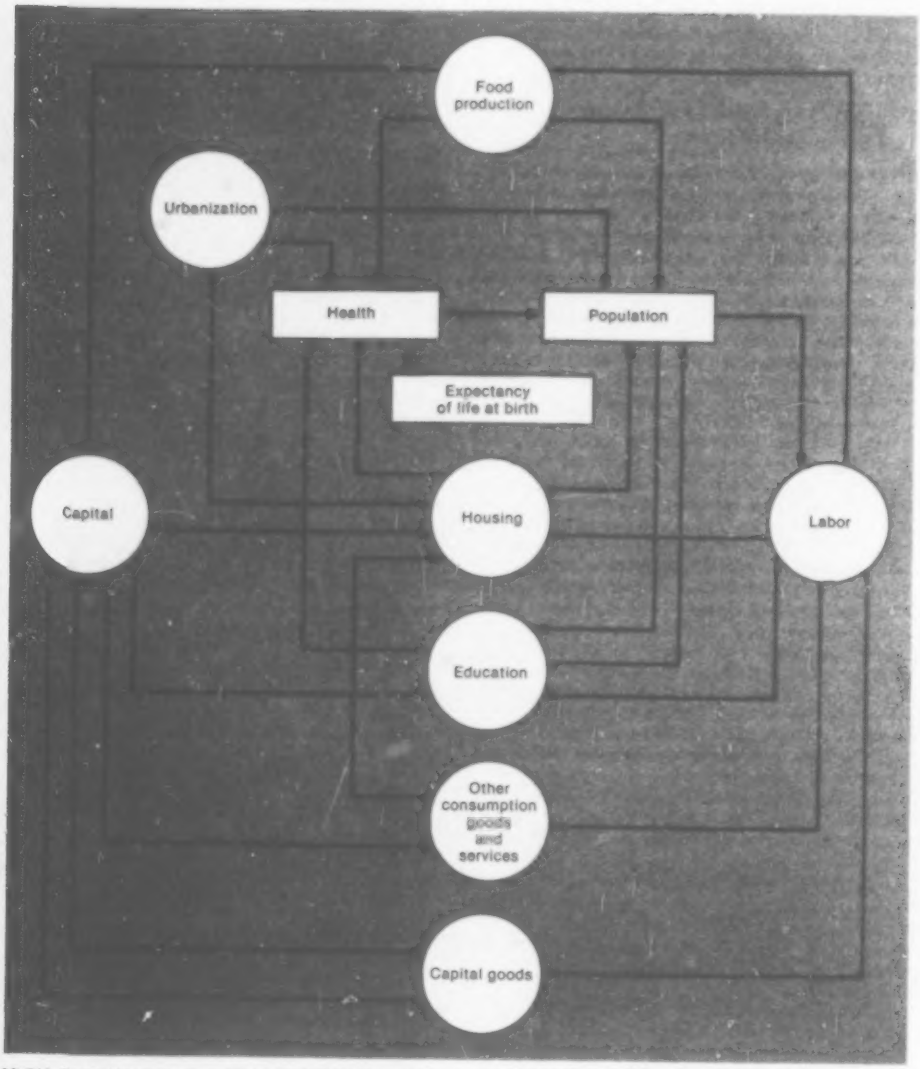
The results of the LAWM standard run are mildly optimistic for all regions except Asia, where the only basic need that is satisfied is education. By 2010 all available land in Asia is being cultivated, which means that the growth of food production is unable to keep up with population growth; although progress continues in housing and income, food availability per capita falls to dangerous levels, and the delay in achieving basic needs causes a delay in reducing population growth. The population projections show a total world population of 6.4 billion by 2000, 1.2 billion in the developed world and 5.2 billion in the developing world. By 2040 the world population reaches 11 billion and is still growing at 1.1 percent per year, due largely to the 1.4 percent growth rate in Asia.

The usefulness of this model for policymakers lacks mainly in its ability to display the effects of adopting a particular broad strategy—that of allocating labor and capital in a manner that corresponds statistically to

[3] A. O. Herrera, et al., *Catastrophe or New Society? A Latin American World Model* (Ottawa: International Development Research Center, 1976), p. 8.

[4] See J. Robinson, "The Latin American World Model," in *The Global 2000 Report to the President* (Washington, D.C.: U.S. Council on Environmental Quality and Department of State, 1980), vol. 2, pp. 638 and 641; and D. H. Meadows, J. Richardson, and G. Bruckmann (eds.), *Groping in the Dark: The First Decade of Global Modeling* (New York: Wiley, forthcoming), p. 97.

Figure A-4.—Basic Structure of LAWM



SOURCE: Graciella Chichilnisky, "Latin American World Model: Theoretical Structure and Economic Sector," in *Proceedings of the Second IIASA Symposium on Global Modeling*, Gerhart Bruckmann (ed.) (Laxenburg, Austria: International Institute for Applied Systems Analysis, 1976), p. 126.

maximized life expectancy. LAWM does not contain policy levers that might be exercised by an individual planner, but the model has nevertheless contributed to the debate on broad strategy by describing an alternative to the present world order.

The United Nations Input-Output World Model (UNIOWM)

The particular goal of this study was to assess the impact of various economic issues and policies on the International Development Strategy for the Second United Nations Development Decade. Specifically, the model was to address the question of whether the existing policies and development targets were consistent with the availability of world resources. Because it uses an input-output approach, the model can be used either to investigate the rates of economic growth achievable given certain constraints (resources, balance of payments, etc.) or to investigate investment and consumption levels that would be consistent with given rates of economic growth.

Unlike the other global models, however, population growth is entirely exogenous in UNIOWM. Although the size and composition of the population affect the rest of the model, there is no feedback from the rest of the model to population. In fact, the model has no population sector as such: it simply uses the population projections prepared by the United Nations Population Division for the 1973 assessment of world population. (This assessment was updated for all countries in 1978, and the discussion below deals with the more recent figures.) These projections, include four variants—high, medium, low, and constant—the constant case is merely a reference projection assuming no change in a country's fertility rate. The medium variant is designed to represent the most likely future demographic trends, based on past and present demographic trends, expected social and economic progress, ongoing government policies, and prevailing public attitudes toward population issues. The high and low variants are intended to reflect plausible variations on these factors.

The fertiltiy assumptions underlying the projections are based on past and present fertility trends in each country, adjusted judgmentally by experts in the U.N. regional population offices around the world and reviewed in the Population Division at U.N. headquarters in New York. These judgments were guided by three general principals:[5]

- Fertility rates will decline as economic and social development takes place.
- Existing or anticipated government policies and programs, as well as nongovernmental activities aimed at such a goal, will expedite the process of fertility decline.
- Once initiated, fertility decline will begin slowly, gain momentum, and then slow down again. For those countries with fertility levels near or below the replacement level, it is assumed that fertility will begin to converge on replacement level before the end of this century.

Judgmental estimates of life expectancy were also prepared for each country, following the general rule that life expectancy would increase by 2.5 years every 5 years until it reaches 55, after which the rate of increase would be less. (For some countries where development has been slow, this rule was changed to allow slower increases.) The projections also take into account assumptions about internal migration (urbanization) in each country.

In the projections prepared by the U.N. in 1978, the population of the world increases from 4 billion in 1975 to 5.9 billion, 6.2 billion, and 6.5 billion by 2000 for the low, medium, and high variants, respectively. Most of this growth occurs in the developing world: the population of the more developed countries increases by only 13 to 21 percent from 1975 to 2000, while the increase for the less developed world is 57 percent in the low variant to 77 percent in the high projections.

The most rapid rate of growth is in Africa, where population increases by 114 percent from 1975 to 2000, and in Central America and the Caribbean, where it increases by 115 percent. China's population is projected to increase by 26 to 37 percent; this is only half the average rate for all developing countries, although it means an additional 235 million to 335 million people by 2000. India will add even more people to its population, an additional 360 million to 480 million people.

These population projections are used by UNIOWM to explore the consequences of the goals adopted for the Second Development Decade. This model has great utility in displaying the results that would occur if these goals were achieved, and as such it has been useful to those planning the broad strategy of the development decade. Unfortunately, the goals and prescriptions of the development decade do not always have a significant influence on actions taken by individual countries.

Global 2000

This study, conducted by an interagency task force that drew on the expertise and models of the entire U.S. Government, is one of the most comprehensive models in terms of the number of variables it examines. However, the separate submodels comprising "the Government's global model" are not linked to each other, and as a result there is no feedback or interaction between sectors. As a result, the population figures do not

[5]United Nations, *World Population Trends and Prospects by Country 1950-2000 Summary Report of the 1978 Assessment* (New York: United Nations, 1979), p. 2.

reflect the model's pessimistic projections of GNP or food production.

The population projections that were used in most sectors of Global 2000 were prepared by the U.S. Bureau of the Census in 1977. Like the U.N. projections, they are presented with high, medium, and low variants for all regions and selected countries. Underlying all three variants are the assumptions that: 1) fertility will decline more or less continuously throughout the period; 2) all countries will have adopted some kind of family planning program by 2000; and 3) the effectiveness and coverage of such programs will increase. The different fertility rates used in the high, medium, and low variants are based on the judgment of experts and reflect the range of uncertainty about current fertility, future development patterns, and government family planning policies. Specific individual judgments are not reported, however.

The final Census Bureau projections extend to the year 2000 and are substantially the same as the U.N. projections: global population grows to 5.8 billion in the low variant, 6.2 billion in the medium variant, and 6.5 billion in the high variant. The population of the developed regions grows to between 1.3 billion and 1.4 billion by 2000, while the less developed regions grow to between 4.5 billion and 5.1 billion.

An alternative set of projections, prepared by the Community and Family Study Center (CFSC) at the University of Chicago under the sponsorship of the Agency for International Development (AID), is also presented in the *Global 2000 Report* but is not used in other sectors. These projections, too, include high, medium, and low variants, but in this case the projected fertility rates are based on a model of fertility decline that relates the rate of decline to the current level of fertility and the strength of family planning efforts within each country. The variants therefore reflect more explicit assumptions about family planning efforts: the high variant assumes that each country maintains its present level of family planning; the medium variant assumes that nations will implement strong family-planning programs by 2000; and the low variant assumes that strong programs will be in place by 1995 and that the effectiveness of these efforts will increase. These assumptions were developed through regression analysis of data for 1968-75, which showed that the strength of family-planning efforts had as much effect on fertility rates as all the measures of socioeconomic development combined.

Because they assume policy changes that would increase the efficacy of family-planning services, the CFSC projections are generally lower than those of the U.N. and Census Bureau: world population reaches 5.8 billion, 5.9 billion, and 6.0 billion by 2000 in the low, medium, and high variants, with the developed regions growing to between 1.2 billion and 1.3 billion and the less developed regions to between 4.5 billion and 4.7 billion. These projections have also been extended to 2050, at which date they show a global population of between 7.8 billion and 8.1 billion people.

The Census Bureau projections, those prepared by CFSC for AID, and all other "stand-alone" projections are useful to the policymaker mainly because they provide an input describing the population conditions under which policy must operate. Such projections are of little direct use to policymakers, but they often become key elements in the analyses that are prepared during the development of policy options.

Other Population Projections

Projections of world population have also been prepared, without the use of a global model, by the World Bank and Harvard University. The World Bank projections, last revised in 1979, were prepared by estimating, for each country, the year in which fertility will reach replacement level.[6] (As defined by the World Bank, "replacement-level fertility" refers to the level at which the number of births equals the number of deaths at the prevailing level of mortality. For countries with high mortality rates the replacement fertility level is considerably higher than 2 children per couple; as mortality declines, fertility must also continue to decline. Thus, a stationary population might not be achieved for more than 100 years after the achievement of replacement-level fertility.) The World Bank projections assume that fertility decline toward the replacement level had started by 1975 in all regions except Sub-Saharan Africa, where the decline was expected to start between 1980 and 1985. These projections show population increasing to 6.0 billion by 2000, with 1.3 billion in the developed world and 4.7 billion in the developing world; the population of the entire world becomes stationary around the year 2175 at a level of 9.8 billion.

In 1977, the Center for Population Studies at Harvard University prepared a single population projection for all countries and regions of the world to the year 2075.[7] In these projections, fertility is assumed to decline to replacement levels by 1990-95 for the developed countries and by 2000-05 for the developing countries; they show the population of the world increasing to 5.9 billion by 2000 and 8.4 billion by 2075.

[6] K. C. Zachariah and My Thi Vu, *Population Projections, 1975-2000 and Long-Term (Stationary Population)* (Washington, D.C.: World Bank, 1979).

[7] G. Littman and N. Keyfitz, *The Next Hundred Years* (Cambridge, Mass.: Harvard University, 1977).

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Strengths and Weaknesses of Population Projection Techniques

Among the studies discussed here there are at least two different goals:

- to describe the long-term behavior of the global system; or
- to provide an accurate, short-term (25 years or less) picture of the world situation.

The long-term global modeling studies (World 3, WIM, LAWM) are clearly concerned with the first goal only. They examine the behavior of the entire global system over the next 50 to 125 years, but they make no attempt to provide accurate forecasts of world population (or any other variable) for 2000. All three studies take great pains to point out that accuracy of individual numbers is not a concern. The studies that limit themselves to projecting population only (World Bank, Harvard) are generally trying to satisfy both goals; they present country-by-country forecasts of population in 2000, but they also present longer views of population growth. The two modeling studies that limit themselves to 2000 (UNIOWM and Global 2000) are clearly interested primarily in the second goal.

These two different goals require the use of two fundamentally different modeling techniques. The first approach (long-term system behavior) considers population as only one of the many elements involved in the integrated behavior of the system: it affects the other sectors and, in turn, is affected by them. With this approach the most important aspects of the population sector are the effects of the rest of the model on population growth. The second technique (accurate short-term forecasts) considers population alone, without integrating it into the world system. It strives for accuracy by making separate projections of the individual countries which are useful in themselves and can also be summed to produce a world total.

Long-Term Integrated Projections

The first technique has obvious advantages for projecting long-term system behavior. Population really is affected by the rest of the global model—by food production, pollution, and economic and social development—and it is essential to take these factors into account in projecting population growth over a long time period. The difficulty with this approach, however, is that the relationships between fertility, life expectancy, and other variables are not known precisely, nor is the historical evidence rich enough to allow these relationships to be estimated with any degree of confidence. In order to include the relationships in their model, therefore, the modelers are often forced to rely on rough estimates and informed guesses. The sensitivity of the model's behavior to these judgments can be tested, of course, but the reliance on judgment does make the model speculative.

Within this first general approach the models discussed here have adopted three variations. World 3 aggregates everything to the level of the world, with no geographical divisions. This was certainly appropriate for the preliminary versions of the model, which were meant to be simple, easily explained outlines of the eventual model. The large effort that went into constructing and documenting World 3 might have been better served if some regional disaggregation had been employed, but this would have at least doubled the amount of work involved in developing, testing, and documenting the model.

The development gap between the developed and less developed world is so large, however, that the two regions cannot properly be considered as one. WIM divides the world into 10 or more regions, and it therefore supplies a much more detailed representation of real-world behavior. In most of the initial WIM runs, however, the link between fertility and the rest of the model was broken and an optimistic fertility assumption imposed, although mortality rates did respond to the rest of the model.

LAWM takes the same general approach to the population sector as the other two models, with one major difference: the model is not designed to simulate actual world conditions, but rather to simulate what would take place if resources were allocated optimally in order to maximize life expectancy. Since this is not the way the world actually operates, LAWM's usefulness is in describing the world that would evolve, *given a particular new mode of behavior*, and not in describing what is likely to happen.

Short-Term Stand-Alone Projections

The second method of projecting population is used by each of the other studies. In this approach the population projections are linked to the rest of the world only insofar as the rest of the world is considered by the experts when they make their judgments about fertility and mortality decline. When the U.N. experts made their estimates, for example, they had in mind some view of the future world which influenced their judgments. Their worldview obviously excluded such disasters as nuclear war and massive famine, or their life expectancy assumptions would not have shown steady increases; but it is impossible to describe just what that worldview was. Indeed, since many different people were involved in this exercise, many different (and possibly conflicting) views of the world were used. It is impossible to say whether these worldviews were internally or mutually consistent, or to what extent any of

them reflect the feedback effects between population and development. The most that can be said is that the experts generally assumed that the forces at work in the past would continue to operate, with the future largely growing out of a continuation of past trends.

Is this assumption of a "surprise-free" future reasonable? All of the global studies discussed here (including the long-term studies as well as Global 2000 and the UNIOWM) apparently consider this assumption reasonable in the short term. None of the studies show large-scale effects on population due to famine or resource shortages before 2000, although WIM shows regional starvation in Asia. In the longer term, however, the situation is different. The three long-term modeling studies show a high likelihood of significant changes beyond 2000: World 3 shows a collapse of population after 2030, WIM shows rapidly increasing deaths due to starvation in South Asia before 2025, and LAWM shows food availability in Asia dropping to starvation levels by 2040 in its standard run. Other studies not based on mathematical models, such as Herman Kahn's *The Next 200 Years*,[8] do not foresee such problems, but the assumption of a long-term continuation of past trends is certainly questionable. The likelihood of such a future actually developing can only be addressed through a comprehensive, integrated study of all factors affecting population growth.

[8]H. Kuhn and A. Wiener, *The Year 2000: A Framework for Speculation on the Next Thirty-Three Years* (New York: Morrow, 1967).

Factors Affecting the Reliability and Accuracy of Population Projections

Differences in purpose and time horizon also affect the reliability and accuracy of the resulting population projections. World 3, for example, attempts to describe the general behavior of the global system to the year 2100. The precision sufficient for such a model is quite different from that desired in the U.N. or Census Bureau population projections, which are used to predict the populations of individual countries in 2000.

Table A-1 shows the results of the studies that have made long-term population projections. There are two notable differences. Due to increasing death rates, population actually begins to decline in the World 3 model after 2025 and presumably would do so for Asia in WIM and LAWM if they had continued beyond 2060; the other projections all show steadily growing popula-

Table A-1.—Comparison of Long-Range Population Projections

Projection source	Projection	Results
World 3	Standard run	Population increases to 7 billion by 2025 then decreases to 4 billion by 2100
	Stationary world	Population stabilizes at 6 billion by 2050
World Integrated Model	Standard run	Population stabilizes at just under 7 billion by 2015. Death rates due to starvation are high in Southeast Asia
Latin American World Model	Standard run	Population reaches 11 billion by 2040 and is still growing at 1.1 percent/yr. Death rates are rising rapidly in Asia
	Second run—improved conditions in Asia	Population reaches almost 11 billion by 2060 and is growing at less than 0.5 percent/yr.
United Nations	1978 population assessment[a]	Population reaches 8 to 12 billion by 2050 and stabilizes at 8 to 14 billion by 2150
CFSC	Medium and low projections	Population reaches 7.8 to 8.1 billion by 2050 and is virtually stationary
World Bank	Standard	Population stabilizes at 9.8 billion by the year 2175
Harvard	Standard	Population reaches 8.4 billion by 2075 and is virtually stationary

[a]These are unpublished, provisional estimates that are not official.

SOURCE: The Futures Group

tion until some stationary level is reached. The second major difference is in the size of that stationary world population, which ranges from a low 8 billion (U.N. low, CFSC, Harvard) to a high of 14 billion (U.N. high). (The lower figures of World 3 and WIM are based on exceptional population programs begun in 1975, and are thus not comparable.)

There is much less variation in the population projections for 2000, which are compared in table A-2 and figure A-5. They vary from a low of 5.8 billion (Census Bureau, CFSC) to a high of 6.5 billion (U.N. and Census Bureau). This much smaller variation indicates the much higher degree of certainty inherent in population projection for periods under 25 years: there is relatively little uncertainty about the number of reproductive-age females between now and 2000, although there is much greater uncertainty with respect to the number of children that each woman will have.

The reasons for the differences among these different projections and their relative accuracy and reliability depend on several factors, among which are:

- projection technique;
- data base for initial population figures; and
- estimates of future fertility and life expectancy.

Table A-2.—Comparison of Population Projections for 2000

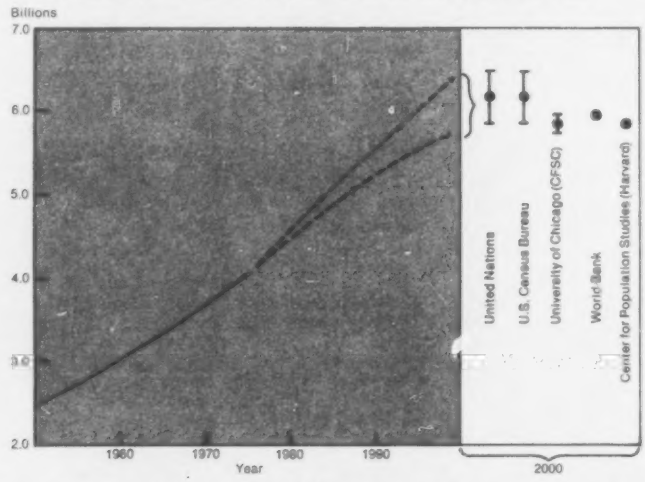
Projection source	Projection	Population in 2000 (billions)
World 3	Standard run	About 8
World Integrated Model	Standard run	6.4
Latin American World Model	Standard run	6.4
United Nations	High	6.5
	Medium	6.2
	Low	5.9
U.S. Bureau of the Census	High	6.5
	Medium	6.2
	Low	5.8
CFSC	High	6.0
	Medium	5.9
	Low	5.8
World Bank	Standard	6.0
Harvard	Standard	5.9

SOURCE: The Futures Group.

Projection Technique

The integrated models include the effects on population from other parts of the global system, and this results in the projection of increasing death rates due to food shortages in at least some parts of the world. The

Figure A-5.—Alternative Projections of World Population in 2000



SOURCES: *World Population Trends and Prospects by Country, 1950-2000. Summary Report of the 1978 Assessment* (New York: United Nations, 1979). *Illustrative Projection of World Population Projections to the 21st Century* (Washington, D.C.: Bureau of the Census, 1979). Amy Ong Tsui and Donald J. Bogue, *Population Projections for the World, 1975-2000* (Chicago: Community and Family Study Center, University of Chicago, October 1977). K. C. Zachariah and My Thi Vu, *Population Projections, 1975-2000 and Long-Term (Stationary Population)* (Washington, D.C.: Population and Human Resources Division, World Bank, 1979). Gary Littman and Nathan Keyfitz, *The Next 100 Years* (Cambridge: The Center for Population Studies, Harvard University, 1977.)

projections that did not employ global models assumed that such disasters would be prevented by technical change, but when forecasters are forced to specify their assumptions mathematically in a model, they were all drawn to similar conclusions: it is unlikely that technological advances alone will allow the world sufficient time to solve the problem of rapidly growing population. The technology assumptions or, indeed, the very structure of the models could well be wrong; but those who develop long-term population projections without the use of models have certainly side-stepped this issue. The problems identified by the integrated global models might be solved through improved technology or different social responses, but none of the projections prepared without models explicitly addresses these questions.

Data Base for Initial Population Figures

All of the recent projections use essentially the same data base for base-year population. Information from national sources is collected by the U.N., the World Bank, and the U.S. Census Bureau, and for most countries all three organizations report the same population totals. However, there is very little available information for some countries; it is therefore necessary to prepare estimates based on incomplete data, and these estimates may vary.

Uncertainty about base-year data is not expressed in the ranges reported by the U.N., and the Census Bureau projections incorporate different base-year data only for China. The recent round of censuses has substantially improved the information available for many countries, particularly in Africa, but for many countries the variation in estimates can still be quite large. China, for example, has not had a census since 1953, and there is a 14-percent difference between the U.N. low and Census Bureau high estimates for China in 1980, a difference about equal to the population of the United States. Similarly, the current population of Nigeria has been estimated at anywhere between 65 million and 85 million, and the most recent census in India found 12 million more people than expected. Even though these differences may be quite large for individual countries, however, they are fairly small once they are summed to the global level: the difference between the highest estimate for world population in 1975 (Census Bureau high series of 4,134 million) and the lowest estimate (World Bank estimate of 4,014 million) is only 3 percent.

Estimates of Future Fertility and Life Expectancy

It has generally been true that projection of populations for countries and regions is relatively accurate in the short term (15 to 20 years) and fairly inaccurate in the long term (over 25 years). The reason for this lies in the nature of population change. Population size changes through three mechanisms: births, deaths, and migration. Except for certain special cases, migration is usually not a major factor in population growth, although movements from rural to urban areas can have significant social, economic, and political consequences. Uncertainty in birth and death rates, on the other hand, can be quite large.

Changes in the birth rate have occurred quite rapidly in the past, and since the reasons for changes in the birth rate are poorly understood, projections of birth rates have tended to err on the side of assuming less change than actually takes place. However, even if the projection of the birth rate misses the mark by a significant amount, the short-term projection of the size of total population may still be reasonably accurate.

After 15 or 20 years, however, errors in projecting birth rates begin to have a much larger effect. By that time children born during the first years of the projections would begin to have children of their own, and any overestimation or underestimation of births will become compounded, leading to exponentially increasing errors in the projection. Since changing death rates affect the mortality of children much more than older age groups, this delayed compounding effect also operates on errors in death-rate projections. For this reason the record of population projections beyond 20 years has not been especially good.

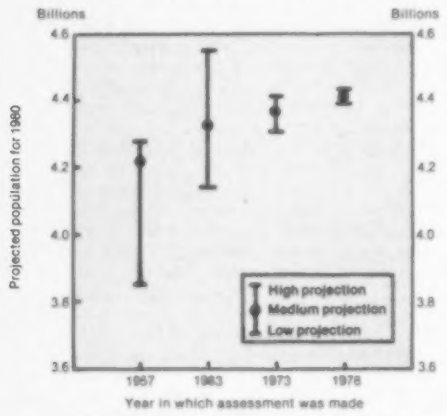
Another crucial factor is the accuracy of the base-year data for birth and death rates. If they are not known with much accuracy, then the projection will have a built-in error and, even if the future change in these rates is correctly forecast, the total error of the projection can be substantial. These factors most seriously affect projections for developing countries, where population data are often scant and unreliable.

The Accuracy of Past and Present Projections

The 1950's and 1960's were a period of rising population growth rates, and U.N. projections made during this period generally underestimated future population. Past U.N. projections of world population for 1980 illustrate this point: the latest assessment in 1978 projected the 1980 population at 4.41 billion; in 1957 it was projected at 4.22 billion (4.3 percent less than the latest estimate); in 1963 at 4.33 billion (1.8 percent less); and in 1973 at 4.37 billion (0.9 percent less) (see fig. A-6).

The major factor affecting these estimates was inaccurate base-year data on death rates, which were 10 or 12 percent lower than estimated. Birth rates, which were estimated more accurately for the base year, have declined more rapidly than predicted. The current esti-

Figure A-6.—United Nations Population Projections for 1980 Prepared Over the Past 25 Years



SOURCES: 1957 and 1963: *World Population Prospects as Assessed in 1963* (New York: United Nations, 1966). 1973: *Selected World Demographic Indicators by Countries, 1950-2000* (New York: United Nations, 1975). 1978: *World Population Trends and Prospects by Country, 1950-2000, Summary of the 1978 Assessment* (New York: United Nations, 1979).

mates of population size, birth rates, and death rates are much improved over what they were in the 1950's and 1960's, but large uncertainties still remain, particularly with the LDCs.

The uncertainty over present birth rates also contributes to uncertainties about future birth rates. In the 1980-2000 period birth rates will probably decline for almost all countries of the world, but projecting the amount of that decline is made difficult by at least four factors:

- uncertainty about how much birth rates have already declined up to the present;
- uncertainty about how many countries will adopt serious family planning policies and how strong those efforts will be;
- uncertainty about how much family planning efforts have contributed to past declines in birth rates; and
- uncertainty about how relevant the experience of family planning effectiveness in countries that have already adopted such efforts will be in those countries which have not yet done so.

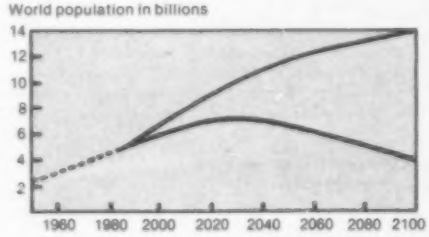
Most of the uncertainty is about birth rates in the developing countries, notably in Africa where there is almost no experience with strong family-planning programs. It is simply impossible to know whether the family-planning experience of countries in Asia and Latin America will be repeated in Africa.

Michael Stoto of Harvard University has calculated the average error in individual country projections made by the U.N. in 1957, based on the difference between predicted and actual growth rates for 40 countries for four time periods: 1955-60, 1955-65, 1955-70, and 1955-75. He found that the absolute average error in annual growth rates for all four time periods was about 0.46 percent, or about 25 percent of the absolute average annual growth rate for the world (about 1.9 percent).[9] The Futures Group has repeated these calculations for the period 1970-75, using projections made by the U.N. in 1973 and actual growth rates taken from its 1978 assessment. Using the same 40 countries, but eliminating those for which no new data are available since 1972, they found an absolute average error of 0.27 percent. Most of the improvement is probably due to the improved quality of base-year data available for the 1973 forecasts, which were used in UNIOWM. If these errors are representative of the kind of errors we can expect in the future, projections of population size 20 years into the future should have an uncertainty range of 10 to 20 percent.

In the longer term the accuracy is much lower. This is due to the greater uncertainty about fertility and mortality trends, the compounding of errors made in the short-term forecasts, and uncertainty about the effects of the rest of the world system (food availability, economic development, pollution) on population growth. The range of projections shown in the studies discussed here—from a projection of steadily growing population reaching a level of 8 to 14 billion, to a projection of population growth and collapse—is representative of the kind of uncertainty that exists in trying to project 50 to 100 years into the future, even if we are willing to exclude such disasters as nuclear war (see fig. A-7).

[9] J. Stover, op. cit.

Figure A-7.—Increasing Range of Uncertainty in Longer Range Projections of World Population



NOTE: For illustrative purposes only, see table A-1 and text for explanation.
SOURCE: Office of Technology Assessment.

APPENDIX B

Agricultural Projections[1]

Introduction

World food supply has been a major concern for global modelers. All of the well-known global models have one or more agricultural sectors; all of them consider measures of food availability as major indices of system performance; and all indicate that performance of the global agricultural system over the next 20 to 100 years is a matter of concern. The apparent discrepancies in their findings result from differences in time horizons, model structure, assumed rates of population and economic growth, the pace of technological progress, and assumptions about the quantity of agricultural land available.

In general, the most optimistic findings come from assumptions of high income growth, low population growth, continued rapid technological progress, and large reserves of agricultural land. Longer time horizons, however, lead to more pessimistic results; and those models that include diminishing returns to land and agricultural inputs show the situation in the global agricultural system getting tighter as time progresses, with South Asia and Sub-Saharan Africa the most severely affected regions.

Purposes, Structures, and Findings

World 3

The World 3 model was intended to examine the interactions between a set of global trends and to identify the long-term impact of their interdependent evolution. as a result, the World 3 model assumes that agriculture must compete with the industrial and service sectors for investment capital and natural resources, and it contains a mechanism by which capital and resources flow to sectors that show signs of supply shortfalls. The model also assumes diminishing returns for investments in land development and agricultural inputs, such as fertilizer and farm machinery; but it excludes both the price mechanism and "disembodied technological progress" (see below). The model does assume, however, that soil degradation and pollution will have negative effects on yields.

In the standard run (see fig. B-1), all indices of agricultural performance improve until the second decade of the next century. Yields and land under cultivation both make considerable gains between 1980 and 2000, and food per capita increases 10 percent despite rapid population growth. Around 2015, however, at about the same time that the limits of arable land are reached, industrial growth so depletes the resource base that investment must be shifted away from agriculture in order to compensate for the increasing costs of resource extraction (see fig. B-2). Industrial output declines, as does the use of agricultural inputs, causing both yields and total production to decline more rapidly in the 21st century than they had expanded in the 20th century (see fig. B-3). Since population continues to increase, the result is widespread hunger, mass starvation, and a delayed but catastrophic decline in global population.

World 3 produces different projections when plausible changes are made in its assumptions, but although the timing of events may be changed by a few decades the net result is the same. For example, given more optimistic assumptions about industrial resources and/or more pessimistic assumptions about agricultural resources, agricultural decline causes investments and resources to be drawn away from industry rather than vice versa; but decline feeds on decline and mass starvation ensues. However, one group of critics reports that they have been able to move the physical limits to agricultural production beyond the time horizon of the model by assuming continuing technical progress in both land-development techniques and high-yield plant varieties, as well as a more rational use of agricultural resources.[2] The structure of World 3 is not sufficiently detailed or flexible, however, to determine what specific policy actions this might entail. Its sensitivity to resource depletion in other policy tests also suggests that the world agricultural crisis, though moved beyond 2100, might still occur.

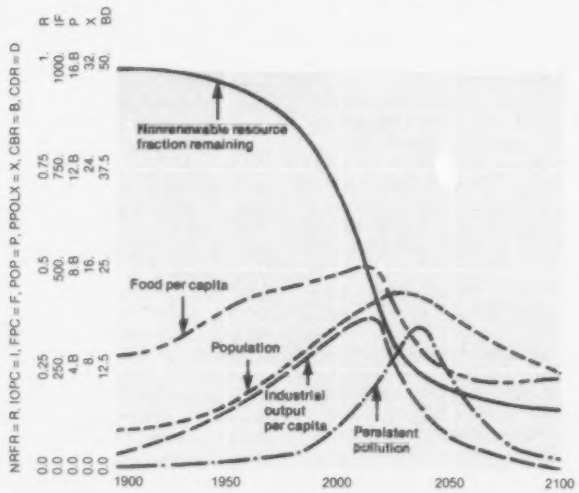
World Integrated Model (WIM)

WIM's projections have greater relevance for food policy analysis because its structure allows a region-by-region investigation of the interaction between population, agriculture, and industrialization. WIM goes into more detail than World 3 and also includes both the price mechanism and a simulation of food and other trade between regions. Environmental effects have been excluded, but the shortened time horizon—2025—is still long enough to encompass the crises foreseen by World 3. WIM also includes numerous "policy levers," making

[1]The following material is based on an OTA working paper prepared by Jennifer Robinson, a fellow of the International Institute of Applied Systems Analysis. For further information on this subject, see OTA's forthcoming assessment, *The Impact of Technology on the Productivity of the Land.*

[2]H. S. D. Cole (ed.), *Models of Doom* (New York: Universe Books, 1973), p. 64.

Figure B-1.—Output From Standard Simulation of World 3



NOTE: Around 2015 the rapid decline of nonrenewable resources forces the industrial sector to shift investments away from industrial and agricultural production to compensate for increasing resource extraction costs. This causes declines in industrial output and agricultural production. The latter, in turn, causes massive starvation and decline of global population by nearly 3 billion over the period 2030–2100.

SOURCE: *Dynamics of Growth in a Finite World*, pp. 501-503.

it a flexible tool for testing different combinations of actions that could be taken to address potential food supply problems.

The WIM standard or "historical" scenario is based on a continuation of present trends, but it nevertheless makes some rather optimistic assumptions about agricultural progress in the developing regions. (The report focuses on South and Southeast Asia because of this region's existing food problems and the number of people involved, but the authors assert that their conclusions "are applicable to Tropical Africa and to any other needy region."[3]) It assumes, for instance, that all available arable land is quickly brought under cultivation and that all technological inputs, such as irrigation systems and farm machinery, will be available as needed. It also assumes "quite optimistically" that the average use of fertilizer per hectare in the region will surpass the present North American level by 2025, at which time South Asia alone will be consuming more fertilizer per year than the entire world consumed in 1960. These factors increase yields by about 1,000 kg per hectare, approximately the same increase achieved by the Green Revolution on the best land before fertilizer prices began to soar. Finally, the standard run assumes that other regions make enough food available to cover any production shortfall in South Asia.[4]

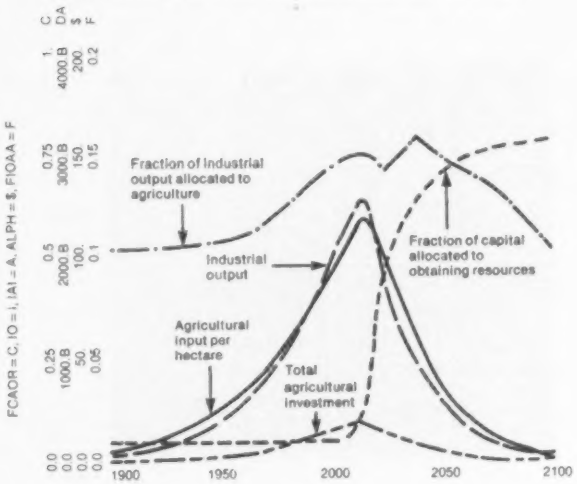
Despite these assumptions, however, and despite the assumption that population will stabilize by 2025, the food supply projections for South Asia are grim (see fig. B-4). The region's annual protein production increases by two-thirds, but the population almost triples and the annual protein deficit grows from 12 million to 50 million tons—an amount equal to the region's own production. Deficits amounting to half the region's protein needs "could never be closed by imports," according to the authors: paying for them would require one-third of South Asia's total economic output and three times its export earnings, and "the physical problems of handling those quantities of food would be incredible."[5] Even if the needed imports were available, the annual

[3] M. D. Mesarovic and E. Pestel, *Mankind at the Turning Point* (New York: Dutton, 1974), p. 121.

[4] Ibid., p. 121.

[5] Ibid., p. 122.

Figure B-2.—Output From Standard Simulation of World 3



NOTE: Around 2015 the rapid decline of nonrenewable resources forces the industrial sector to shift investments away from industrial and agricultural production to compensate for increasing resource extraction costs. This causes declines in industrial output and agricultural production. The latter, in turn, causes massive starvation and decline of global population by nearly 3 billion over the period 2030-2100.

SOURCE: *Dynamics of Growth in a Finite World*, pp. 501-503.

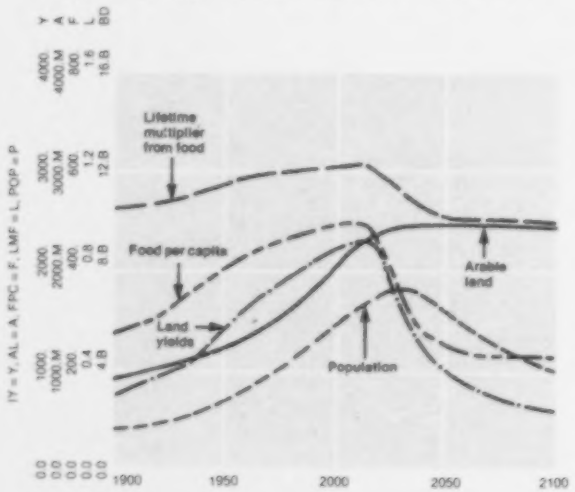
number of child deaths caused by malnutrition will double by 2005 (see fig. B-5).

Policy tests conducted with WIM indicate that only a combination of food aid, population policies, and balanced development can avert tragedy in South Asia. In the "isolationist" or "tragic" scenario, in which food imports are not available because of balance-of-payments constraints, annual child mortality is twice as high as in the standard run; it rises sharply after 1985, peaks in 2010, and declines thereafter only because of the delayed impact of earlier deaths on the later number of fertile women (see fig. B-5). A third scenario, designed to investigate policies aimed at food self-sufficiency for South Asia, assumes that virtually all regional investment is shifted from industrial development to agriculture; but the results indicate that yields per hectare, after initially rising faster than in the standard run, would peak around 2000 and decline thereafter. This decline occurs because the agricultural sector would not be able to maintain its growth without the industrial base that must supply it with fertilizer and machinery. By 2025, gross regional product is only half what it was in the standard run, and the region is left with even fewer means of paying for food imports.

In further policy tests, WIM shows that population policies aimed at achieving an equilibrium fertility rate could have a significant effect on food deficits and child mortality, even in the absence of imports, if they are implemented quickly enough. Such policies, if initiated in 1995, would not reduce the number of child deaths in the "isolationist" scenario; if initiated in 1990, however, the same policies might save more than 150 million lives (see fig. B-5). If initiated in 1975, these policies could avoid more than 500 million child deaths.[6] The need for food imports would be significantly reduced and would come later in the period, but the cost would still be prohibitive. In a final scenario, therefore, it is assumed that the developed regions provide South Asia with sufficient investment aid to develop "its own exportable and competitive industrial specialization," whose exports could pay for most of its food imports.[7]

[6] Ibid., p. 124 and fig. 9-9.
[7] Ibid., p. 127.

Figure 8-3.—Output From Standard Simulation of World 3



NOTE: Around 2015 the rapid decline of nonrenewable resources forces the industrial sector to shift investments away from industrial and agricultural production to compensate for increasing resource extraction costs. This causes declines in industrial output and agricultural production. The latter, in turn, causes massive starvation and decline of global population by nearly 3 billion over the period 2030–2100.

SOURCE: *Dynamics of Growth in a Finite World*, pp. 501-503.

Latin American World Model (LAWM)

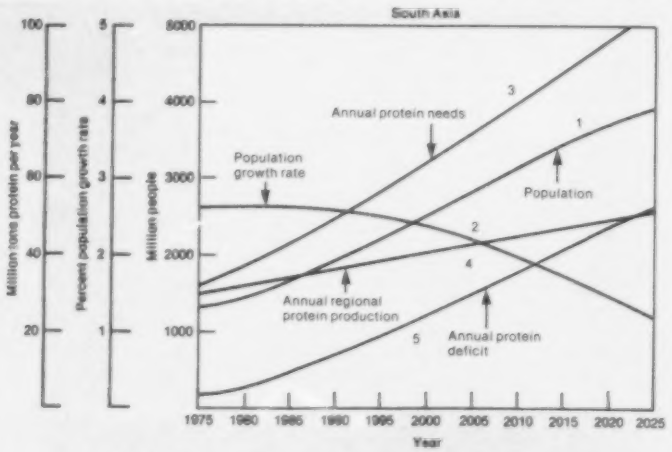
LAWM was developed to show that, given optimal resource allocation and the universal objective of satisfying basic human needs, the global system need not be troubled by physical limits. Because development proceeds "autarchically" in each of its four regions, international food trade is unimportant and is largely excluded from the model. Environmental effects are also omitted, as are food prices; and although the model assumes diminishing returns on land development and yield-enhancing inputs, it also assumes "disembodied technological progress" (see below) in the form of an automatic 1.0-percent annual increase in the productivity of the food and agriculture sector.

The food and agriculture sector is by far the most complicated in LAWM, containing three subsectors —agriculture, livestock, and fisheries—among which capital and labor are allocated in patterns that shift over simulated time as the return on investment diminishes in each. Each of these subsectors contains at least one optimistic assumption. The agriculture subsector, for instance, assumes that fertilizer will be available in unlimited quantities and at constant prices throughout the simulation period, and that processing losses in the developing regions will decrease automatically each year until they reach the levels currently found in the developed region. Similarly, the livestock subsector assumes that agricultural wastes and excess agricultural products will be used for animal fodder once human needs are met, thereby transforming food wastes into a measure of meat consumption. The fisheries subsector assumes a maximum sustainable catch of 120 million metric tons per year, considerably higher than the level indicated by more recent reports.

The model assumes no policies to limit population growth, other than the general improvement of living conditions. However, it does assume a radical, egalitarian redistribution of income and consumption within regions, which greatly increases the effective demand and relative benefit for the lowest socioeconomic strata.

Given these optimistic assumptions, the standard run of this optimization model indicates that all regions except Asia will be able to satisfy their own food needs

Figure B-4.—World Integrated Model Standard Run for South and Southeast Asia



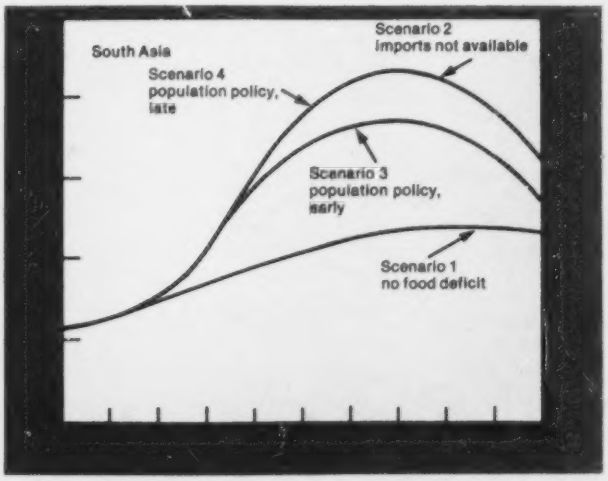
The "standard" scenario is based on the assumption that a population policy is initiated that leads in about 50 years to equilibrium fertility. Thereby, the population grows from 1.3 billion in 1975 to 3.8 billion in 2025 (curve 1) while the growth rate of this region declines from a little over 2.5 to 1 percent (curve 2). It is furthermore assumed that the population is adequately fed, and thus no starvation would slow down the population growth. Then the protein needs (curve 3) of South Asia would increasingly surpass her own protein production (curve 4) so that at the end of the 50 year period considered, the protein deficit (curve 5) is larger than her own estimated protein production of around 50 million tons. The grain import necessary to cover this protein deficit (due to the fact that more than 90 percent of all the protein consumed in South Asia is of vegetable origin this is also a calorie deficit) would increase to about a half billion tons annually by 2025 and would continue to grow. This amount is twice the present North American grain crop, and even if it were available for export to South Asia, it would pose practically insurmountable transportation and distribution problems. The increase of the regional production in South Asia is based on making all potentially arable land available for cultivation and on achieving a steadily rising yield per hectare. These production levels assume productivity comparable to that achieved by introduction of improved grains — the "Green Revolution" — on the best irrigated land in India, which is probably an overly optimistic assumption.

SOURCE: *Mankind at the Turning Point.*

within 30 years. The agriculturally relevant variable in the simulation outputs is the total daily caloric intake per capita: in the developed nations, it rises to 3,200 calories by 1980 and equilibrates at that level thereafter (fig. B-6); in Latin America it rises to 3,000 calories by 1990 and stabilizes at that level, which is lower due to differences in climate and diet (fig. B-7); Africa achieves and stabilizes at a similar level around 2008. In Asia, however, the only need that is met is education; food per capita peaks at less than 3,000 calories per day in 2010 and declines steadily thereafter (fig. B-8). This agricultural collapse is similar to the catastrophe foreseen by WIM in both its standard and self-sufficiency runs:

> The problem in Asia arises in the food sector. By 2010, all available land is being cultivated. Thereafter, economic effort in the sector is devoted to increasing livestock and fisheries. This, however, is not enough to feed the growing population adequately, and consumption drops rapidly to below the minimum needed for survival.
>
> The rapid increase in the cost of producing food, due to the development of new land for agriculture, takes resources from the rest of the economy, causing backward-

Figure B-5.—Child Mortality in Four Scenarios of the World Integrated Model



Scenario 1 is the standard scenario. Scenario 2 shows the consequences for Scenario 1 if imports are not available to cover the protein deficiency gap. Scenario 3 shows the reduction in child mortality achieved over Scenario 2 by a population policy instituted in 1990. Scenario 4 shows the consequences of implementing the same population policy 5 years later. Composite of Figures 9-2 and 9-4, *Mankind at the Turning Point*, pp. 122 and 128. The projection of Scenarios 2 and 4 are essentially identical in the original.

SOURCE: *Mankind at the Turning Point*

ness and also hindering the satisfaction of the other basic needs. In summary, the delay in reaching adequate levels of well-being leads to a sustained high population growth rate, and a vicious circle develops: increased population and the increased cost of producing food make it more and more difficult to satisfy basic needs.[5]

Rather than show the full details of this catastrophe, the modelers have truncated the Asia run at 2040, 20 years before simulations for other regions are terminated. The authors advocate effective population policies and the use of nonconventional foodstuffs to avoid mass starvation in Africa, but then present neither specific details nor policy tests to support these recommendations.

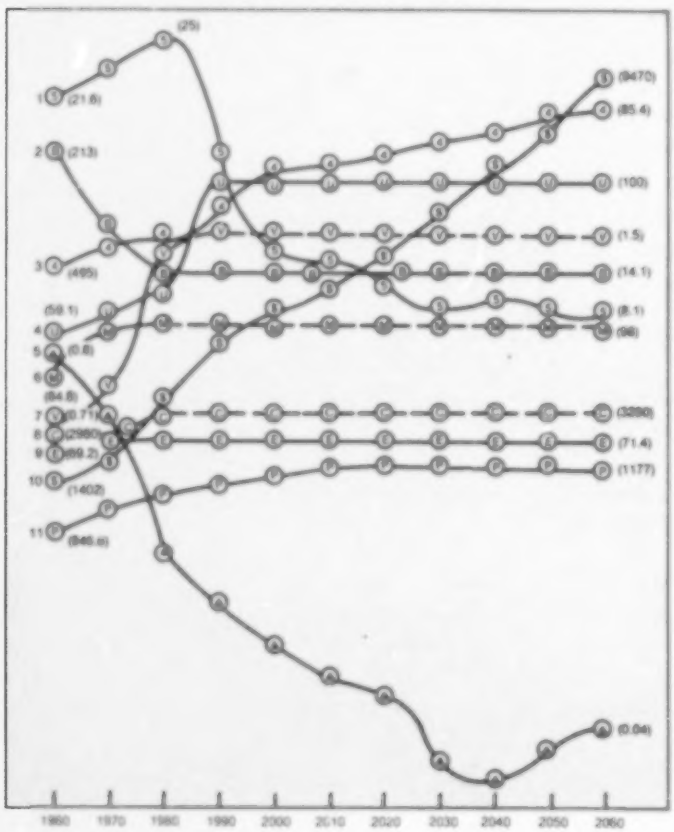
The policy tests that were conducted by the LAWM team indicate that capital transfers from the developed region would have a negligible impact on the food shortage in Asia. They also show that technological stagnation after 1980 would lead to a similar collapse in Africa as well as Asia and that, in the absence of regional income redistribution, the satisfaction of basic needs (though possible) would require three to five times more resources and two to three more generations of human suffering.

[5]A. O. Herrera, et al., *Catastrophe or New Society? A Latin American World Model* (Ottawa: International Development Research Center, 1976), p. 29.

United Nations Input-Output World Model (UNIOWM)

UNIOWM is the only model that does not indicate potential problems in supplying food to all the world's people over the next two decades. Its optimistic findings, however, result in part from its purpose and structure: its projections do not show what is likely to happen in the agricultural sector, but rather what trends would be required in order to achieve the goals of the U.N.'s Second Development Decade. The input-output approach is well suited for consistent accounting of intersectoral flows, but it is not particularly well adapted for agricultural analysis because it is totally linear. Many biological processes, on the other hand, are

Figure B-6.—Time Period and Conditions Required for Developed Countries to Satisfy Basic Needs to Given Levels

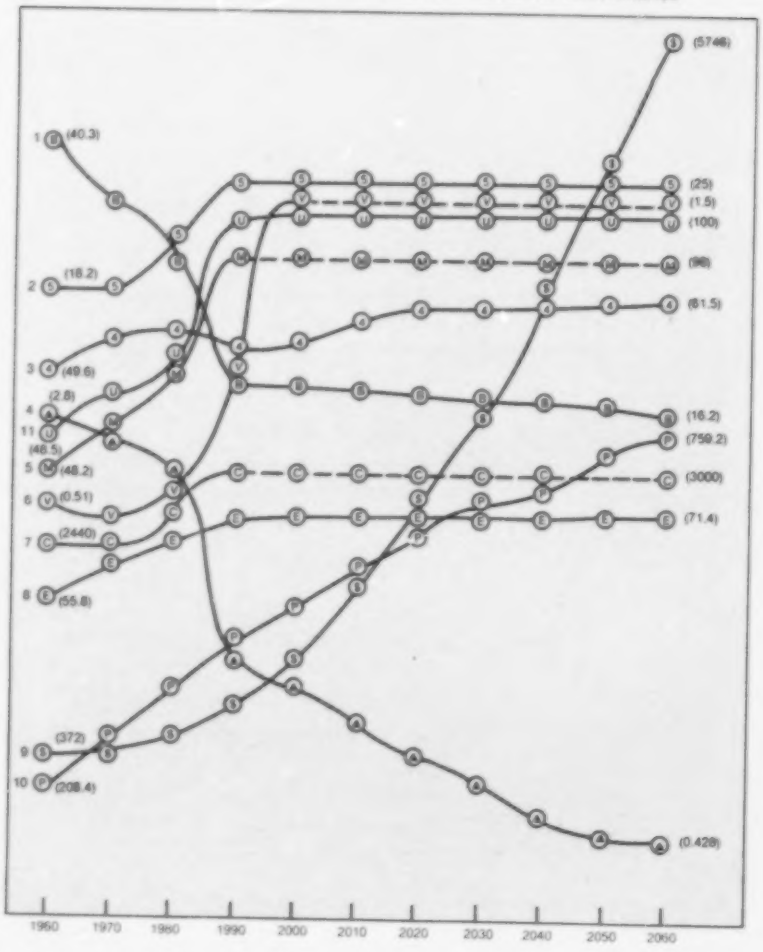


Key:

1 (5) Percent GNP allocated to sector 5
2 (B) Birthrate
3 (4) Percent GNP to other goods and services
4 (U) Urbanization
5 (▲) Population growth rate
6 (M) Enrollment
7 (V) Houses per family
8 (C) Total calories per capita
9 (E) Life expectancy
10 ($) GNP per capita
11 (P) Total population

SOURCE: *Catastrophe or New Society?*

Figure B-7.—Latin American World Model Simulation for Latin America

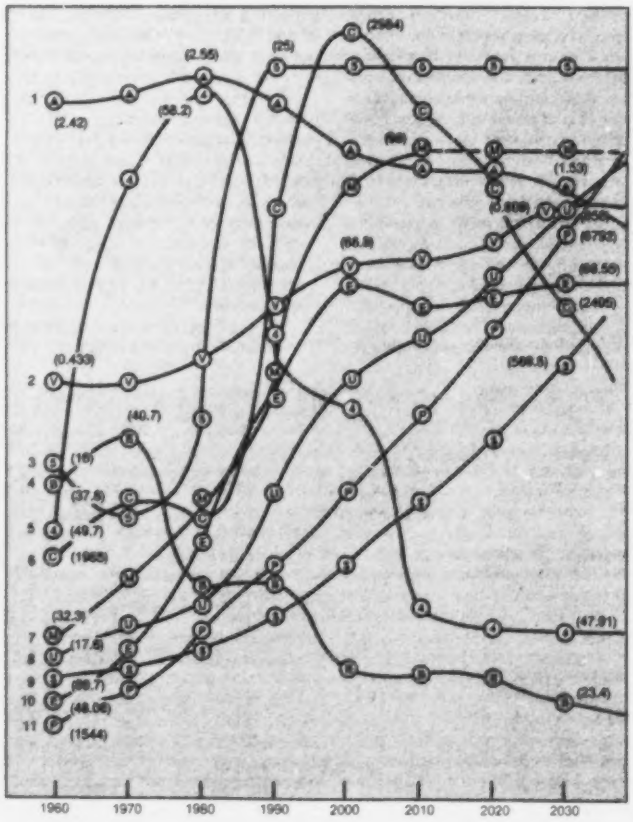


Key:

1 (B) Birthrate
2 (S) Percentage of GNP allocated to sector 5
3 (4) Percentage of GNP allocated to sector 4
4 (▲) Population growth rate
5 (M) Enrollment
6 (V) Houses per family
7 (C) Total calories
8 (E) Life expectancy
9 ($) GNP per capita in 1960 dollars
10 (P) Total population
11 (U) Urbanization

SOURCE: *Catastrophe or New Society?* p. 88

Figure B-8.—Latin American World Model Simulation for Asia



Key:

1 (▲) Population growth rate
2 (V) Houses per family
3 (5) Percentage of GNP allocated to sector 5
4 (B) Birthrate
5 (4) Percentage of GNP to other goods and services
6 (C) Total calories per capita
7 (M) Enrollment
8 (U) Urbanization
9 ($) GNP per capita in 1960 dollars
10 (E) Life expectancy
11 (P) Total population

SOURCE: *Catastrophe or New Society?* p. 92

highly nonlinear, and many critical agricultural flows (such as the externalities associated with overgrazing and deforestation, or the changing probabilities of pest damage under different cropping systems) are difficult to include in an input-output framework. In addition, UNIOWM shows linear returns on investments in agricultural inputs and must depend on off-line analysis to determine the amount of land under cultivation. These features produce odd results in some places, such as a 169-percent increase in the productivity of Japanese farmlands, which are already intensively cultivated, and a 387-percent increase in the Middle East.

In general, the projections show rapid increases for almost all agricultural variables in almost all regions, with the most dramatic gains being made in the developing countries. Over the 30 years of the simulation (1970-2000), global grain production almost triples and global production of animal products more than triples (table B-1). Developing regions achieve astounding increases in both land productivity and total agricultural production (table B-2), and by 2000 all regions have reached an average daily per capita consumption of over 2,400 calories and 66 grams of protein (table B-3). These results, however, do not seem to be accompanied by any symptoms of economic or financial stress. Agricultural prices, relative to general price levels, increase only 14 percent over 30 years. In no region does investment in irrigation or land development grow by more than a few percent per year, and in many regions agricultural investments actually decline. If anything, the pressure on the agricultural system appears to be easing in 2000: rates of agricultural demand growth decrease slightly in the last decade of the simulation, largely because incomes have risen to a point where consumers spend less of each additional dollar of income on food.

It should be repeated that these projections are intended only to prove the *technical* and *physical* feasibility

Table B-1.—Global Agricultural Output in UNIOWM Standard Scenario

	1970	1980	1990	2000
Total agricultural output (billions of 1970 dollars):				
Developed	255.8	296.0	332.2	415.4
Developing group I[a]	23.8	42.1	78.5	151.7
Developing group II	120.1	186.4	322.8	529.9
World	399.7	524.5	733.5	1097.0
Agricultural output per capita (billions of 1970 dollars):				
Developed	0.2615	0.2776	0.2878	0.3381
Developing group I	0.0665	0.0884	0.1222	0.1770
Developing group II	0.0526	0.0652	0.0910	0.1227
World	0.1104	0.1192	0.1372	0.1713
	1970–1980	1980–1990	1990–2000	1970–2000
Rate of growth of agricultural output[b] (percentage):				
Developed	1.4	1.2	2.2	1.6
Developing group I	5.7	6.2	6.6	6.4
Developing gourp II	4.3	5.4	5.0	5.1
World	2.7	3.4	4.0	3.4
Grain: total domestic demand				
	1970–1980	1980–1990	1990–2000	
Rate of growth[b] (percentage):				
Developed countries	1.6	3.4	2.1	
Developing group I	3.7	5.3	6.3	
Developing group II	3.6	4.6	4.4	
World	2.7	4.1	3.7	
Animal products: total domestic demand				
	1970–1980	1980–1990	1990–2000	
Rate of growth[b] (percentage):				
Developed countries	2.25	2.26	1.34	
Developing group I	5.53	5.73	6.55	
Developing group II	4.33	4.93	4.82	
World	3.13	3.54	3.40	

[a]Group I includes mineral rich developing countries, group II is comprised of mineral poor developing countries.
[b]Average annual compound.

SOURCE: *The Future of the World Economy*, pp. 39, 42, 43.

Table B-2.—Land Requirements and Yields in 2000 in UNIOWM Standard Scenario
(Index, 1970 = 100 percent)

Region	Agricultural output	Arable land	Land productivity
Developed market:			
North America	196	111	194
Western Europe (high-income)	130	100	162
Japan	176	100	269
Oceania	192	183	162
Centrally planned:			
Soviet Union	164	100	215
Eastern Europe	143	100	186
Asia (centrally planned)	488	120	278
Developing market:			
Latin America (medium-income)	495	166	311
Latin America (low-income)	532	140	328
Middle East	950	126	487
Asia (low-income)	506	115	331
Africa (arid)	409	131	282
Africa (tropical)	438	152	324

SOURCE: *The Future of the World Economy*, p. 40.

Table B-3.—Regional Daily per Capita Food Consumption in 1970 and 2000, UNIOWM Standard Scenario

Region	Kilo-calories (thousands) 1970	2000	Proteins (grams) 1970	2000
Developed market:				
North America	3.2	3.2	96	100
Western Europe (high-income)	3.0	3.2	91	105
Japan	2.4	3.2	71	117
Centrally planned:				
Soviet Union	3.2	3.2	92	108
Eastern Europe	3.1	3.2	93	108
Asia (centrally planned)	2.1	2.5	59	79
Developing market:				
Latin America (medium-income)	2.4	3.0	60	86
Latin America (low-income)	2.2	2.9	50	74
Middle East	2.0	2.9	53	92
Asia (low-income)	2.0	2.4	52	66
Africa (arid)	2.5	2.5	72	78
Africa (tropical)	2.2	2.8	62	87

SOURCE: *The Future of the World Economy*, p. 39.

of certain U.N. development goals The modelers involved in the UNIOWM have tended to merely state their findings and allow readers to draw their own policy conclusions. Like WIM and LAWM, however, their model points to the need for increased food self-sufficiency and export earnings in the LDCs. Findings relevant to food and trade policy include the following:

> The most pressing problem of feeding the rapidly increasing population of the developing regions can be solved by bringing under cultivation large areas of currently unexploited arable land and by doubling and trebling land productivity. Both tasks are technically feasible but are contingent on drastic measures of public policy favorable to such development and on social and institutional changes in the developing countries.[9]

Self-sufficiency in food is a promising kind of "import substitution" for reducing balance of payments deficits in developing countries.[10]

> A relatively stable increase in the prices of minerals and agricultural goods exported by the developing countries, as compared to the prices of manufactured goods, is one way of increasing the export earnings of these countries and closing their balance of payments deficit . . . . For developing regions which are not large net exporters of minerals or agricultural goods, the main way to reduce the potential trade imbalance is to significantly decrease their import dependence on manufactured products . . . while . . . increasing their share of world exports of some manufactured products, particularly those emanating from light industry. . . . Increase in aid; measures to create a more favorable climate for a better mix of capital investment flows to these regions; [and] . . . reduction in the financial burden arising from foreign investment are important, but . . . secondary . . . compared to . . . changes in the commodity markets and trade in manufactured products.
>
> To ensure accelerated development two general conditions are necessary: first, far reaching internal changes of a social, political and institutional character in the developing countries, and second, significant changes in the world economic order.[11]

Global 2000

The agricultural projections in Global 2000 were generated by the grain-oilseed-livestock (GOL) model that was developed in 1974 by the U.S. Department of Agriculture (USDA) to assist in the formulation and execution of U.S. agricultural and trade policy. Maintained by the Foreign Demand and Competition Division of USDA's Economics, Statistics, and Cooperative Service, GOL is a computer-based static equilibrium econometric model that was specifically designed to capture the interaction between the largely cereal-oriented food economies of the developing regions and the livestock-oriented food economies of the industrialized regions. For the purposes of Global 2000, GOL was supplemented with three independently developed submodels that project the availability of arable land, the total food supply (including fisheries and other miscellaneous sources), and the use of fertilizer in each region. GOL has been used to analyze the potential impact of U.S. parity pricing policies on international food trade and to analyze the potential impact of alternative assistance programs for the U.S. Agency for International Development.

[9]W. Leontief, et al., *The Future of the World Economy* (New York: Oxford, 1977), p. 21.
[10]Ibid., p. 22.
[11]Ibid., p. 23.

The greatest advantage of the GOL is its scope and detail: it consists of 28 interactive regional submodels containing equations for the supply, demand, trade, and prices of 16 different food commodities. USDA analysts claim that the model represents 70 to 80 percent of world production and consumption and an even larger percentage of food trade. Its greatest weakness is that, as a static equilibrium model, it is incapable of representing market behavior that is in disequilibrium. In addition, dynamic factors such as population and income growth must be calculated exogenously in advance and thus are not affected by the model's operation. These factors were adjusted to be more consistent with other sectors of Global 2000, but a number of minor discrepancies exist between the GNP and population projections and the corresponding GOL assumptions. Other critical assumptions incorporated into GOL include the following:

- no major wars, changes in the international economic order, or natural disasters such as climatic change or large-scale land degradation;
- no increase in world grain reserves to keep pace with population growth, no change in Western Europe's somewhat protectionist agricultural and trade policies, and no major increase in U.S. food trade with the Soviet Union, Eastern Europe, or the People's Republic of China; and
- continued technological progress (measured in yields) comparable to the rapid growth of the last 20 years, with the industrialized nations and (to a lesser extent) the LDCs taking advantage of technology according to the incentives provided by changes in the prices of production factors and food commodities.

GOL generated four alternative sets of agricultural projections for Global 2000, using different assumptions about population, income, weather, and energy prices:

- **Alternative I,** the standard or "baseline" projection, assumes medium rates of population and income growth, constant weather, and constant real energy prices at 1974-76 levels.
- **Alternative IA,** a variant of the standard run, assumes a doubling of real energy prices by 2000.
- **Alternative II,** the optimistic upper-bound projection, also assumes constant real energy prices, but assumes lower population growth and higher per capita income growth, as well as more favorable weather conditions than over the last 25 years.
- **Alternative III,** the pessimistic lower bound projection, assumes a doubling of real energy prices, higher population growth, lower income growth, and less favorable weather conditions.

Detailed regional projections for 1985 and 2000 of total and per capita grain and food production, consumption, and trade are presented in tables B-4 and B-5. "Other African LDCs" are included in order to show the model's most problematic region, and South Asia is included to allow comparison with the results of other global models. World grain production and regional per capita consumption figures are compared in figures B-9 and B-10, which illustrate the range of uncertainty that results from different exogenous assumptions. In case of energy variables, according to the report, "[the] range reflects not so much uncertainty about petroleum price increases as uncertainty about . . . the ability of farmers to maintain or expand production while shifting away from energy-intensive inputs."[12]

Within this range, the results indicate a near doubling of global food supply between 1970 and 2000. Roughly speaking, this comes from a 50-percent increase in the developed regions and a 150-percent increase in the LDCs. In both cases the increase comes from fertilizer use rather than land development: global cultivated land increases less than 5 percent by 2000, whereas the application of fertilizer per hectare increases 160 percent, doubling in the developed regions and quadrupling in the LDCs. However, because population growth is more rapid in the LDCs than in the developed regions, LDC consumption generally increases more rapidly than production. As a result, international food trade will expand briskly, with the United States and Argentina benefiting most from the larger markets (see table B-6). Gains in per capita consumption are small and unevenly distributed in the LDCs: Tropical Africa shows net declines in per capita food consumption even in the most optimistic scenario, and gains in South Asia are less than 10 percent at best; on the other hand, per capita increases of 10 to 30 percent are projected for Latin America and East Asia. The real price of food on the world market is projected to increase by between 30 and 115 percent, depending on the scenario; under the higher figure, the poorest LDC importers could find themselves priced out of the market as they were in 1973-75.[13]

These findings lead to several conclusions relevant to food policy. The world has the physical and economic capacity to meet substantially increased food demand through 2000, but to do so it must maintain the near-record growth rates of the 1960's and 1970's. Significant increases in food trade will be needed to balance excess demand in food-deficit Western Europe, Japan, and the centrally planned economies, as well as parts of developing Africa and Asia. Variations in supply will become more important as the world's productive capacity is used at higher levels, particularly if there is no increase in world grain reserves. This suggests, according

[12] *The Global 2000 Report to the President* (Washington, D.C.: U.S. Council on Environmental Quality and Department of State, 1980), vol. 2, p. 85.
[13] Ibid., vol. 2, p. 556.

Table B-4.—Grain and Total Food Production, Consumption, and Trade (Alternatives I, II, III) As projected by the GOL Model for Global 2000

	1985						2000					
	Grain (million metric tons)			Food (1969–71 = 100)			Grain (million metric tons)			Food (1969–71 = 100)		
	I	II	III	I	II	III	I	II	III	I	II	III
Industrialized countries:												
Production	569.5–	525.9	568.1	535.2	126.6–118.1	127.3	118.2	739.7–	679.1	730.0	683.3	157.0–143.7	157.1	143.5
Consumption	466.2–	465.3	515.7	455.9	121.0–116.6	127.1	114.6	648.4–	610.8	667.6	590.2	156.8–147.7	165.7	143.6
Trade	+ 63.3–	+ 60.6	+ 52.4	+ 80.3				+ 91.3–	+ 68.3	+ 42.4	+ 93.1			
United States:														
Production	304.0–	297.1	297.5	309.7	137.8–134.9	135.1	140.2	416.0–	402.0	409.8	414.0	184.3–178.5	181.8	183.5
Consumption	210.9–	199.8	229.5	194.4	119.6–114.0	129.2	111.2	290.2–	272.4	+ 325.0	+ 256.6	160.3–151.3	178.3	143.2
Trade	+ 93.1–	+ 97.3	+ 68.0	+ 115.3				+ 126.0–	+ 129.6	+ 84.8	+ 157.2			
Centrally planned countries:														
Production	557.0		589.5	534.0	138.2	143.7	130.1	722.0		748.0	691.0	174.0	179.5	166.1
Consumption	566.0		597.5	578.5	143.3	143.8	139.1	756.5		755.0	730.0	179.9	179.2	173.2
Trade	– 29.0		– 8.0	– 44.5				– 36.5		– 9.0	– 39.0			
Less developed countries:														
Production	471.7–	490.7	485.3	470.5	154.4–161.4	148.9	152.9	735.0–	740.6	757.0	745.3	244.5–247.7	268.2	246.4
Consumption	526.0–	522.3	529.7	508.3	163.4–162.8	165.1	157.1	789.8–	772.4	780.4	799.4	247.8–242.8	261.2	249.0
Trade	– 54.3–	– 31.6	– 44.4	– 35.8				– 54.8–	– 31.8	– 33.4	– 54.1			
Latin America:														
Production	101.0–	111.9	104.3	107.6	158.7–174.8	163.6	168.4	182.6–	185.9	195.4	188.4	279.5–284.4	288.4	288.1
Consumption	99.5–	98.2	103.7	97.2	162.7–160.7	169.2	159.2	168.8–	166.0	172.5	160.6	269.7–265.3	275.4	257.0
Trade	+ 1.5–	+ 13.7	+ .6	+ 10.4				+ 13.8–	+ 19.9	+ 22.9	+ 27.8			
North Africa/Middle East:														
Production	56.2–	56.8	57.3	53.0	146.3–148.1	149.6	138.9	92.2–	89.0	94.5	88.1	252.5–257.8	259.3	240.4
Consumption	80.6–	79.6	80.9	79.9	167.4–165.1	168.1	165.8	127.5–	123.7	125.5	132.5	276.1–267.3	271.4	287.7
Trade	– 24.4–	– 22.8	– 23.6	– 26.9				– 35.3–	– 29.7	– 31.0	– 44.4			
Other African LDCs:														
Production	47.1–	50.0	48.6	45.5	150.7–160.2	155.6	145.5	61.3–	63.7	63.1	61.5	197.1–204.9	203.0	197.8
Consumption	51.9–	51.5	51.5	48.5	161.2–160.0	160.0	150.5	63.3–	63.0	60.7	62.0	198.4–196.4	189.1	193.2
Trade	– 4.8–	– 1.5	– 2.9	– 3.0				– 2.0–	+ .7	+ 2.4	– .5			
South Asia:														
Production	184.2–	188.0	190.0	178.6	154.0–156.5	158.9	149.3	265.0–	259.0	269.0	271.0	221.8–216.8	225.2	226.9
Consumption	199.7–	199.0	200.0	186.3	158.7–158.2	159.0	146.0	284.3–	275.7	290.7	293.9	226.2–219.4	231.3	233.9
Trade	– 15.5–	– 13.0	– 10.0	– 7.7				– 19.3–	– 16.7	– 21.7	– 22.9			
Southeast Asia:														
Production	38.3–	41.4	38.6	39.6	179.1–194.3	180.6	185.5	62.0–	65.0	62.6	64.1	295.3–310.0	298.3	305.6
Consumption	30.5–	30.5	29.9	30.7	168.0–168.0	164.5	169.1	47.9–	47.0	46.0	49.9	266.8–263.6	257.8	280.4
Trade	+ 7.8–	+ 10.9	+ 8.7	+ 8.9				+ 14.1–	+ 18.0	+ 16.6	+ 14.2			
East Asia:														
Production	44.9–	44.8	46.5	43.2	155.8–154.7	161.4	149.7	71.9–	73.0	72.4	72.2	251.4–255.3	253.1	252.4
Consumption	63.8–	63.5	63.7	61.3	173.1–172.3	172.9	166.2	98.0–	97.0	95.0	100.5	267.7–264.9	259.4	274.6
Trade	– 18.9–	– 18.8	– 17.2	– 18.1				– 26.1–	– 24.0	– 22.6	– 28.3			
World:														
Production	1,608.2–	1,583.6	1,642.9	1,540.7	141.5–140.5	144.5	137.0	2,196.7–	2,141.7	2,233.0	2,119.6	194.0–191.0	198.0	191.5
Consumption	1,608.2–	1,583.6	1,642.9	1,540.7	141.5–140.5	144.5	137.0	2,196.7–	2,141.7	2,233.0	2,119.6	194.0–191.0	198.0	191.5

NOTE: In trade figures, + indicates export; minus sign indicates import.

SOURCE: *The Global 2000 Report to the President*, vol. 2, pp. 91–92.

to the report, that "[the] agricultural and trade policies of a small number of importers and exporters will play an increasingly dominant role in determining the quantities and prices of food traded on the world market." The United States is projected to play an increasingly dominant role in balancing world supply and demand by expanding or contracting production in order to moderate price fluctuations.[14]

The Global 2000 environmental projections related to agriculture suggest that food production could fall significantly below the quantities projected by GOL due to soil deterioration, pest- or pathogen-control problems, water shortages caused by deforestation, and unstable supplies of energy-related inputs. U.S. and foreign government policies will play a large role in deciding whether or not environmental problems seriously erode global agricultural production potential. These concerns will probably seem more important to the industrialized nations than to the LDCs, which are more likely to face the pressing problem of expanding production to meet rapidly expanding food needs, often regardless of long-term environmental costs.[15] Model-comparison exercises similarly suggest that if GOL were more integrated—i.e., if it gave greater attention to the interactions between agriculture and other economic sectors or environmental conditions—its results would probably be less optimistic:

> The rising food prices and regional food shortages projected in the agricultural model would be intensified by the fact that agriculture is not the only sector wanting capital to cope with increasing population demands and diminishing returns. Land degradation caused by intense pressure on the land and by pollution would tend to

[14] Ibid., vol. 2, pp. 77-90.

[15] Ibid., vol. 2, p. 89.

Table B-5.—Per Capita Grain and Total Food Production, Consumption and Trade (Alternatives I, II, III) As projected by the GOL Model for Global 2000

	1985						2000					
	Grain (kilograms)			Food (1969–71 = 100)			Grain (kilograms)			Food (1969–71 = 100)		
	I	II	III	I	II	III	I	II	III	I	II	III
Industrialized countries:												
Production	718.9–	683.8	719.2	669.7	112.9–104.5	115.2	105.0	838.5–	769.8	847.5	716.9	128.8–118.4	131.8	108.8
Consumption	613.7–	587.3	656.9	569.4	108.8–104.9	115.2	102.1	735.0–	692.4	798.3	619.2	127.7–121.2	139.1	110.0
Trade	+ 105.1–	+ 76.5	+ 62.3	+ 100.3				+ 103.5–	+ 77.4	+ 49.2	+ 97.7			
United States:														
Production	1,331.2–	1,301.0	1,324.6	1,322.1	124.8–122.2	124.2	124.0	1,697.4–	1,640.3	1,719.1	1,479.5	156.0–151.1	157.8	137.4
Consumption	923.5–	874.9	1,021.9	829.9	108.5–103.4	116.9	98.7	1,183.3–	1,111.5	1,363.3	917.7	135.9–128.3	154.6	107.9
Trade	+ 407.7–	+ 426.1	+ 302.7	+ 492.2				+ 514.1–	+ 528.8	+ 355.8	+ 561.8			
Centrally planned countries:														
Production	411.5		452.5	369.6	116.7	127.6	107.2	451.1		489.2	375.3	129.6	135.6	112.8
Consumption	432.5		458.5	400.4	122.4	125.0	115.9	473.9		495.1	396.5	135.8	138.4	119.0
Trade	– 21.0		– 6.0	– 30.8				– 22.8		– 5.9	– 21.2			
Less developed countries:														
Production	182.0–	189.4	190.4	178.3	101.7–106.5	106.7	99.1	195.6–	197.1	210.2	176.6	109.5–110.8	119.5	99.1
Consumption	203.0–	201.6	207.8	191.8	107.7–106.7	110.8	101.8	210.2–	205.5	219.4	189.5	111.0–108.6	116.7	99.9
Trade	– 21.0–	– 12.2	– 17.4	– 13.5				– 14.6–	– 8.4	– 9.2	– 12.9			
Latin America:														
Production	247.7–	247.4	264.3	259.6	108.2–118.9	114.9	113.0	305.9–	311.4	346.6	286.0	131.5–133.7	147.8	123.6
Consumption	244.0–	240.8	262.8	234.5	110.9–109.6	118.7	106.9	282.8–	278.1	306.0	243.8	127.1–125.1	136.7	110.8
Trade	+ 3.7–	+ 33.6	+ 1.5	+ 25.1				+ 23.1–	+ 33.3	+ 40.6	+ 42.2			
North Africa/Middle East:														
Production	201.8–	203.9	209.0	188.4	87.2– 88.3	91.0	80.1	218.3–	222.5	239.9	186.6	95.9– 98.2	107.4	80.3
Consumption	289.4–	285.8	295.1	284.1	101.8–100.3	104.2	99.7	301.8–	292.8	318.6	283.7	105.9–102.2	112.9	98.4
Trade	– 87.6–	– 81.9	– 86.1	– 95.6				– 83.6–	– 70.3	– 78.7	– 95.0			
Other African LDCs:														
Production	130.7–	138.7	136.2	125.5	98.1–104.3	102.3	94.0	109.0–	113.2	123.8	108.0	81.2– 84.5	92.7	80.5
Consumption	144.0–	142.9	144.4	133.7	105.0–104.2	105.3	97.3	112.5–	112.0	119.1	106.8	81.3– 80.9	86.3	78.5
Trade	– 13.3–	– 4.2	– 8.1	– 8.3				– 3.6–	+ 1.2	+ 4.7	– 0.8			
South Asia:														
Production	170.0–	171.7	177.1	160.7	104.6–105.6	108.9	98.8	174.0–	170.0	178.1	152.1	107.0–104.6	109.6	93.5
Consumption	184.3–	183.7	186.4	167.7	107.8–107.4	109.0	98.0	186.7–	181.0	192.4	164.9	109.2–105.8	112.5	96.4
Trade	– 14.3–	– 12.0	– 9.3	– 7.0				– 12.7–	– 11.0	– 14.3	– 12.8			
Southeast Asia:														
Production	273.6–	295.8	282.0	278.1	116.3–126.4	120.1	118.4	301.9–	316.5	322.7	282.5	129.2–135.9	138.7	120.4
Consumption	217.9–	217.9	218.5	215.6	108.9–108.9	109.2	107.6	233.2–	228.5	237.1	219.9	117.1–114.6	119.2	110.0
Trade	+ 55.7–	+ 77.9	+ 63.6	+ 62.5				+ 68.7–	+ 87.5	+ 85.6	+ 62.6			
East Asia:														
Production	139.9–	138.9	148.4	131.9	104.6–104.9	111.2	98.5	161.1–	163.5	168.7	140.4	121.1–122.8	126.9	105.0
Consumption	198.8–	197.8	203.3	187.1	116.2–115.6	118.9	109.2	219.5–	217.3	221.3	195.5	128.7–127.3	129.7	114.2
Trade	– 58.9–	– 58.9	– 54.9	– 55.2				– 58.5–	– 53.8	– 52.6	– 55.1			
World:														
Production	337.7–	332.6	354.4	315.4	109.5–108.5	114.0	103.0	352.2–	343.2	373.0	302.0	117.0–114.5	126.0	104.0
Consumption	337.7–	332.6	354.4	315.4	109.5–108.5	114.0	103.0	352.0–	343.2	373.0	302.0	117.0–114.5	126.0	104.0

NOTE: In trade figures, + indicates export; minus sign indicates import.

SOURCE: *The Global 2000 Report to the President*, vol. 2, pp. 93–94.

make the projection of agricultural output more gloomy.[16]

Other Agricultural Projections

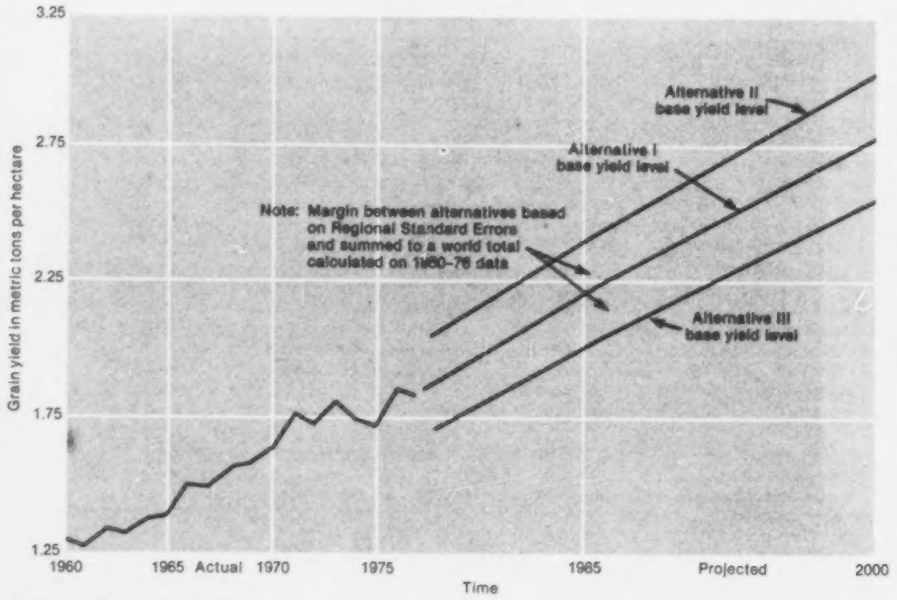
One of the most disaggregated and mathematically elegant models of the world food system is the Model of International Relations in Agriculture (MOIRA), commissioned by the Club of Rome in 1973 and carried out by Dutch economists and agronomists with the support of the Government of the Netherlands.[17] It was originally constructed to investigate the consequences for the food system of a doubling of the world's population, and it is explicitly concerned with the problem of world hunger. Its specific purposes are: 1) to describe the global food situation in terms of its underlying causal factors; and 2) to evaluate policy measures, particularly international ones, that might redirect future developments towards improvements in the world food situation. The latter purpose focuses on the growth of food deficits in poor countries and the effect of agricultural and trade policies in the rich countries on the development of food production and consumption in the Third World.

Structurally, MOIRA is similar to GOL in that both of them address only the agricultural sector, leaving critical factors such as population, GNP, and energy inputs as exogenous variables. Both of them rely heavily on traditional economic theories and techniques to represent a world food system controlled by market supply, demand, and prices. They differ, however, in what they disaggregate: whereas GOL disaggregates crops but considers only one class of consumers in each of its 28

[16]Ibid., vol. 2, p. 672.

[17]H. Linnemann, et al., *MOIRA—Model of International Relations in Agriculture* (Amsterdam: North-Holland Publishing Co., 1979).

Figure B-9.—World Grain Yields, Actual 1960–1976 and Projections to 2000 Under Alternatives I, II, and III of GOL for Global 2000



SOURCE: *The Global 2000 Report to the President*, vol. 2, p. 76.

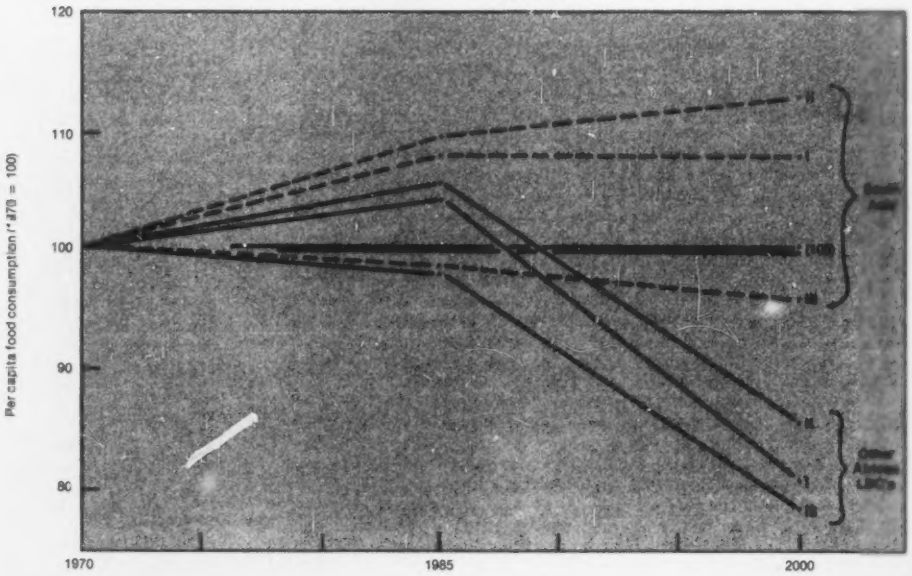
regions, MOIRA considers only one agricultural output—consumable protein—but disaggregates consumers into 12 different income-and-occupation classes in each of 106 individual nations, which are linked through an equilibrium model of international food trade. This structure allows the model to simulate conflicts of interest between producing and consuming nations or between agricultural and nonagricultural sectors within nations, which in some ways makes it a better tool for food policy analysis.

The model is solved by yearly increments over a 50-year simulation (1960-2010), with the world market assumed to clear each year and the world market price (along with factor costs and technical considerations) assumed to affect the next year's production decisions. Each nation's producers are assumed to operate in such a way as to maximize expected sectoral—not individual—income. National markets buffer themselves from international markets by tariffs or price subsidies that affect the motivations of producers, but a "seepage" effect tends to drive domestic prices toward world prices.

In its normal mode of operation, MOIRA's structure shows demand being steadily increased by population growth and income growth, which leads to higher prices, which in turn stimulate additional supply. Due to the costs of expanding production, however, supply increases more slowly than demand, and low-income consumers who cannot purchase food at the going market price "demand" less food than they actually need to avoid malnutrition. In short, only high prices can increase production, but high food prices relative to consumers' incomes will result in people going hungry. This outcome reveals how, in one critic's view, "this model structure emphasizes the fact that, in today's world —and in the foreseeable future—it is poverty, much more than supply constraints, that is the cause of world hunger."[18]

[18]D. H. Meadows, J. Richardson, and G. Bruckmann (eds.), *Groping in the Dark. The First Decade of Global Modeling* (New York: Wiley, forthcoming), pp. 112-115.

Figure B-10.—Projected Regional Per Capita Food Consumption for South Asia and Sub-Saharan Africa in 1985 and 2000 Under Alternatives I, II, and III of GOL for Global 2000
(Index 1969–71 = 100)



NOTE: For illustrative purposes only.

SOURCE: *The Global 2000 Report to the President*, vol. 2, pp. 93–94.

Table B-6.—Projected Net Exporters of Wheat Under Alternative I-A (Medium Growth, Rising Energy Prices) of GOL for Global 2000[a]

	(Million metric tons)							
	1970		1985		2000		Average annual growth percent	
	Exports	Percent share	Exports	Percent share	Exports	Percent share	1970–85	1985–2000
United States	17,881	39	48,838	58	58,226	57	7	1
Australia-New Zealand	8,300	18	12,165	15	16,084	16	3	2
Argentina	1,640	4	6,410	8	13,974	14	10	5
Canada	11,750	26	15,288	18	7,311	7	2	−1
South Africa	60	—	839	1	4,108	4	19	11
U.S.S.R.	4,799	11	127	—	1,995	2	−22	20
India	—	—	—	—	166	—	—	—
Euro Six	1,170	3	—	—	—	—	—	—
Total	45,600	101[b]	83,667	100	101,864	100	4	1

[a]These figures are representative of the lowest level of disaggregation within the GOL model and are cited to illuminate the GOL methodology. While Department analysts are reasonably confident of the GOL model's computations at higher levels of aggregation, they would prefer that these more disaggregated projections not be cited as Global 2000 Study projections.
[b]Does not sum to 100 due to rounding.

SOURCE: *The Global 2000 Report to the President*, vol. 2, p. 557.

The standard run of MOIRA, based on a continuation of present trends, assumes moderate population growth, "relatively high" growth in nonagricultural GNP, and no new policy interventions. The results of this scenario shows steady increases in agricultural production (fig. B-11) and per capita protein consumption (fig. B-12), along with higher but unstable world market prices (fig. B-13). Nevertheless, there is also a large increase in the number of people below the minimum food standard (fig. B-14). Nutritional gains are greater in the developed regions than in the LDCs, and significantly lower in South Asia than in the LDCs as a whole. The LDCs show a decrease in food self-sufficiency, and North America becomes even more dominant as the leading food exporter. Sensitivity tests conducted to assess the effect of exogenous variables on these results produced the following results:

- lower growth rates in nonagricultural GNP (3.5 rather than 7 percent in the LDCs) reduces demand, prices, and output, resulting in a 35-percent increase in world hunger;
- lower population growth rates (about half the rate of the standard run) also results in lower prices and output, but does produce a 30-percent reduction in world hunger; and
- internal income redistribution outside each country's agricultural sector (gradually reducing present inequities by half their magnitude over the 1975-2010 period) leads to significantly higher effective demand and to price increases 50 percent greater than in the standard run, and, although it increases the food imports of the LDCs, it also reduces world hunger by about 50 percent.

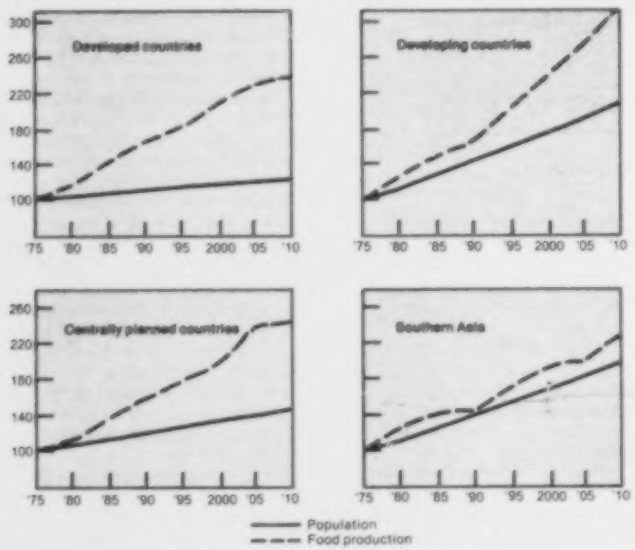
The authors conclude from this last test that "the hunger problem is, to a large extent, a problem of income distribution," but they are quick to point out the limitations of their model. The general trends it projects are more significant than its precise numerical results, but these sensitivity tests all point to a similar outcome:

> . . . all simulation runs with alternative assumptions regarding exogenous variables have one thing in common: if policies remain unchanged, the number of people who cannot obtain sufficient food will increase.[9]

As a consequence, the authors have used MOIRA extensively for policy testing, with the objective of discov-

[9]Linnemann, et al., op. cit., p. 13.

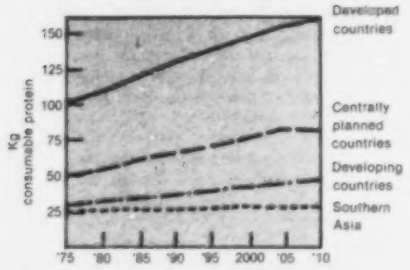
Figure B-11.—Projections of Population and Food Production in MOIRA, Standard Run



NOTE: In all regions production increases faster than population, although in Southern Asia gains are quite modest.

SOURCE: Extracted from *MOIRA*.

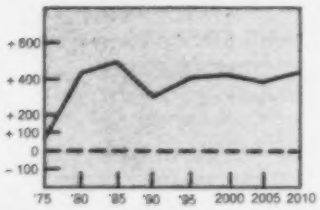
Figure B-12.—Projection of Annual Per Capita Protein Consumption From MOIRA, Standard Run



NOTE: Greatest gains occur in the developed countries. There is a steady gain in developing regions, but Southern Asia shows very little gain.

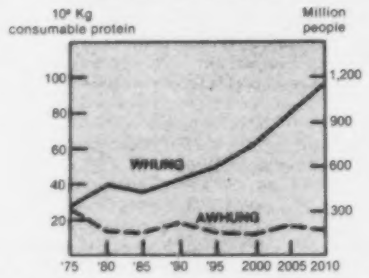
SOURCE: Extracted from *MOIRA*, p. 29.

Figure B-13.—Food Prices on World Market in MOIRA, Standard Run



SOURCE: Extracted from *MOIRA*, p. 291.

Figure B-14.—Total World Hunger (WHUNG) and Hunger in the Agricultural Sector (AWHUNG) in MOIRA, Standard Run



NOTE: Right axis shows number of people with a consumption level below the minimum food standard. Left shows total food deficit in 10⁹ Kg consumable protein.

SOURCE: Extracted from *MOIRA*, p. 291.

ering what actions might be taken by the rich nations to contribute effectively to the goal of reducing world hunger. The four basic policy tests involve two measures intended to achieve a redistribution of available food and two measures intended to stimulate food production in developing regions:

- **Reduction of food consumption in the rich countries,** which might be achieved by shifting consumption patterns (i.e., fewer animal products), results in a low world market price that weakens the incentives to production and thereby leads to increases in total world hunger.
- **Food aid,** if it is purchased by the rich countries at the prevailing world market price and distributed to those under the food norm in such a way that it does not disturb local markets, is capable of eliminating world hunger almost completely. This optimistic scenario, which requires the developed nations to devote about 0.5 percent of their GNP to food aid, differs from the first in that it raises world market prices, particularly between 1980 and 1990, and thereby stimulates additional production.
- **Regulating international food trade,** in order to stabilize world market prices at a relatively high level, also proves to be an effective way to stimulate production and improve the food situation in the LDCs, particularly under the assumption of low economic growth outside the agricultural sector. Such a policy might be difficult to implement, however, because it would require the rich nations to create buffer stock and to regulate their imports and exports in order to keep prices at desired levels; under some conditions this might require North America to give up its leading position as a food exporter.
- **Liberalizing international food trade,** which would require rich countries to cease protecting their domestic markets from world food prices, causes lower food prices and (over the long term) considerably more hunger. Because this policy lowers production in the LDCs, it also increases the developed regions' share of food exports, with the greatest increases coming from North America; in short, it benefits the rich at the expense of those less fortunate.

The policy package the authors find most effective combines price stabilization and food aid. They conclude that "[as] long as the rich nations are able and willing to provide the funds" there is little potential for conflict between these apparently contradictory objectives. However, they also found that deliberate changes in income distribution in the poorest countries would

"remarkably strengthen the positive effect of food aid and world market regulation."[20] This "global food supply policy" would nevertheless require a concerted effort on the part of the rich nations to adapt their domestic production to the international demand and supply situation.

Strengths and Weaknesses of Projection Techniques

Anyone putting an agricultural sector into a global model must arrive at formulations for the determinants of agricultural production (supply) and consumption (demand). What he includes and how he includes it determines the results his model will produce, although his biases may strongly influence the way he interprets these results. For example, all of the models except UNIOWM indicate there will be problems supplying food to at least some of the world's people over the next 20 years. The reason for this finding is fairly straightforward: all of the models except UNIOWM show increasing costs for land development as the amount of undeveloped land decreases, and all except UNIOWM show diminishing returns to agricultural inputs. In short, the models show agricultural problems because they include agricultural limits.

However, their other major similarity—advocacy of drastic social and political change—appears to be something modelers interject into their models rather than something they learn directly from the models. The conclusions drawn from global models often suggest that the only way to avert major catastrophe is to alter some difficult-to-change trend such as fertility, investment rate, or income distribution; but the models themselves are insufficiently detailed to tell what these changes would mean in practice.

Table B-7 compares how the six models treat some of the basic factors influencing agricultural systems, with factors affecting demand on the left, factors affecting supply on the right, and factors affecting both supply and demand in the center. It shows that models are more alike in what they leave out (make exogenous) than in what they include, but even when a variable is endogenous there are differences in how models treat it. All of these differences affect results in some way, although it is sometimes difficult to establish how. For example:

- Differences in aggregation cause large differences in the *form* of model output, but they frequently have no effect on model *behavior* other than making results more or less detailed, or more or less difficult to interpret. Experimentation with different levels of aggregation has led many modelers to prefer more aggregated structures, which give nearly identical results at a much lower cost. On the other hand, sometimes disaggregation does matter: if one were to aggregate grains and livestock in GOL, UNIOWM, or any other model that differentiates between agricultural products, one would probably observe a change in the way the model responds to high prices and/or poor harvests.
- Structural differences that have no effect under one set of circumstances may be all-important under another. For example, the soil degradation mechanism in World 3 has almost no effect on the model's standard run, but when nonrenewable resource constraints are removed the resulting pollution causes agricultural yields to plummet, and the system must begin devoting a large part of its industrial output to rescuing the agricultural sector.
- Seemingly different structures can behave similarly, while seemingly similar structures behave very differently. For example, World 3, UNIOWM, and LAWM all lack price mechanisms; however, both the LAWM and World 3 will cause investment to flow in the direction of a sector that shows signs of supply shortfalls, while UNIOWM contains no such mechanism.
- Important structural features may be buried in accounting matrices. For example, a zero entry in an input/output matrix, or an assumption of non-substitutability between two classes of agricultural commodities, could greatly affect intersectoral flows in any of the multicommodity models (GOL, UNIOWM, and WIM).

In short, the way a model's structures affects its results can be complicated, so much so that modelers themselves are often at a loss to explain system behavior. There are, however, some situations in which model behavior is easily traced to model structure, and there are many other situations where this influence is at least a plausible explanation. LAWM's pronounced tendency to rapid urbanization, for instance, results from the fact that its optimization routines are based on statistical research that showed a high correlation between living in cities and life expectancy; LAWM's behavior with regard to housing and education can be explained in the same way. Similarly, the relatively pessimistic projections of GOL and World 3 with respect to food per capita certainly result in part from the fact that neither model includes labor in its agricultural production functions; the relatively optimistic findings of LAWM and MOIRA, on the other hand, probably owe something to their inclusion of labor.

MOIRA assumes that farmers produce the quantity of outputs that will maximize their profits at a given price level for agricultural inputs, which explains why

[20]Ibid., p. 329

Table B-7.—Comparison of Structural Assumptions in Six Global Models

	Demand		Supply and demand				Supply	
Model	Population	Income growth	Intersectoral interaction	Prices	Trade	Constraints	Technology	Environment
World 3	Births and deaths endogenous, 4 cohorts, 1 region	Endogenous, driven by supply of capital and inputs	Agriculture, industry, compete for investment. If one sector fails it brings others down	Omitted, implicit in links between supply and demand	Omitted	Diminishing returns for land investment and agricultural inputs, depletable mineral resources	Embodied in capital stock, properties may be changed by policy, no automatic progress in disembodied technology	Soil deterioration and pollution affect yields
WIM	Births and deaths semi-endogenous, 10 + regions, 85 cohorts	Endogenous, driven by supply of capital and inputs	Multisectoral, input-output with detail on energy and machinery, energy shortage reduces production, agricultural development needs industrial growth	Explicit, endogenous, by sector	Fixed and other imports constrained by balance of payments	Diminishing returns on land investment and agricultural inputs, depletable energy resources	Embodied in capital stocks, investment shifted by price and profit criteria, no automatic progress in disembodied technology	Omitted
UNIOWM	Exogenous, 15 regions	Exogenous, fast enough to meet Ufe targets	40 sector input-output, no intersectoral competition, just accounting of intersectoral flows	Exogenous, by sector for all sectors, based on input cost projections	All sectors, import substitution exogenously determined	None, linear returns to inputs	Exogenous updates of input-output coefficients changes production efficiencies, i.e., automatic disembodied technological progress	Emissions of pollutants calculated for each sector, no feedback to yields
MOIRA	Exogenous, 108 nations, 6 rural and 5 urban income groups, urban-rural migration endogenous	Exogenous	Nonagricultural growth affects income, hence agricultural demand. Relative income levels in agriculture and nonagriculture affect migration	Domestic food prices endogenous, policy controlled, world food price balances supply and demand	Food only, detailed representation of trade policies, assuming policy tries to keep agricultural incomes in line with nonagricultural incomes	Diminishing returns on land investment and agricultural inputs	Embodied shifts through producers investing to maximize profits. Disembodied progress automatic	Omitted (to be included in MOIRA2)
LAWM	Births and deaths endogenous, 4 regions, maximizes life expectancy	Endogenous, driven by supply of capital and labor	5 sectors compete for capital and labor, allocation based on sectoral contribution to basic needs fulfillment. Agriculture needs capital sector inputs	Omitted	Unimportant, mostly omitted	Diminishing returns on land investment and yields	Disembodied progress automatic, in agriculture 1 percent per year gain in efficiency	Omitted
G2000	Exogenous, 28 regions	Exogenous	Sensitive to energy prices, little other interaction, within agriculture, high level of interaction between grain and livestock	Agriculture, endogenous by commodity; energy, exogenous	Multicommodity trade in agricultural products, some policy representation particularly for United States	Apparently linear returns on inputs, no limits	Disembodied progress automatic, following trends observed in the recent past	Omitted in GOL, analyzed verbally

SOURCE: Office of Technology Assessment

measures that drive up agricultural prices are successful as a means of reducing hunger. However, profit maximization may be a better approximation of the behavior of rich farmers than of poor farmers (who may not be able to borrow funds for expanding production, and who may resist giving up their traditional agricultural practices), and for this reason MOIRA probably overestimates the response to price incentives in the developing countries, thereby underestimating hunger in its rapid-economic-growth scenarios. Finally, as discussed below, the structural decision to make important parts of the system exogenous often results in a model whose reliability and accuracy are heavily dependent on the projections used to drive the model.

Factors Affecting the Reliability and Accuracy of Agricultural Projections

Model Structure and Assumptions

Most global modelers enjoin readers against taking their numerical forecasts as precise estimates. Nonetheless, comparison of numerical results, in conjunction with comparison of structures and assumptions, is a useful means of determining why various global models make the projections they do. Table B-8 compares the projections made by six models for key agricultural variables in 2000, including food production, prices, expansion of cultivated land, and yields. To eliminate differ-

Table B-8.—Comparison of Projected Values of Critical Agricultural Variables in Different Global Models

	Food production	Price increase	Cultivated land		Yield	Global food/capita	Regional food/capita		
World 3	260	Not relevant	130		120	109	Not included		
UNIOWM	285	114	Region	Arable land	Land productivity	158		Calories	Protein
	grain		Developed market			grain	South Asia	120	127
	274		North America	111	194	155	Africa (tropical)	127	140
	livestock		Western Europe (high-income)	100	162	animal	Latin America (low-income)	125	143
			Japan	100	289	products	Latin America (high income)	132	148
			Oceania	183	162				
			Centrally planned						
			Soviet Union	100	215				
			Eastern Europe	100	186				
			Asia (centrally planned)	120	278				
			Developing market						
			Latin America (medium-income)	166	311				
			Latin America (low-income)	140	328				
			Middle East	126	467				
			Asia (low-income)	113	331				
			Africa (arid)	131	282				
			Africa (tropical)	152	324				
MOIRA	244	522	Not documented		Not documented	140		High	Low
	high growth	high growth				high growth	South Asia	125	75
	185	113				108	Africa (tropical)	164	100
	low growth	low growth				low growth	Latin America	166	117
Global 2000	191 to 201	130	104		160	126		High	Low
	grain	optimistic			to	optimistic	South Asia	113	96
	191 to 198	to			190	104	Other African LDCs	86	78
	food	215				pessimistic	Latin America	137	111
		pessimistic							
LAWM			Not documented				Africa	~130	
							Asia	~150	
							Latin America	~120	
WIM			Not documented				South Asia	98	

NOTE: Scaled such that 1970 = 100. (For illustrative purposes only. Some of these numbers have been read off of imprecise plotted output and may err by as much as 5 or 10 percent).

SOURCE: Office of Technology Assessment.

ences in measurement, values for 2000 have been indexed to their values in 1970. Generally, world aggregates are used because the models use very different regional aggregations. It has not been possible to include values for all models, because not all models calculate all variables and model documentation often fails to present needed data. Indeed, lack of information has made it impossible to include either the WIM or the LAWM in most calculations.

Projected food production in 2000 ranges from 185 to 285 percent of 1970 figures, an increase equivalent to average annual compound growth rates varying from 2.0 to 3.5 percent. UNIOWM and World 3 give the highest figures; the MOIRA low-growth scenario and the Global 2000/GOL projections give lowest. Price projections vary far more than supply projections: the MOIRA's high-growth scenario, at one extreme, shows a price increase of over 400 percent (most of which, incidentally, occurs before 1985); on the low side, the MOIRA low-growth scenario and UNIOWM project price increases of below 15 percent. Columns 3 and 4 show how much of the increase in output is attributable to expanded cultivation and how much to increased yields; the figures show that World 3 anticipates land expansion, GOL yield increases, and UNIOWM both. Finally, columns 5 and 6 show global and selected regional figures for per capita food intake. From the differences between columns 5 and 1, one can infer that global population growth is faster in World 3 than in other models and slower in Global 2000. The regional figures, however, show that there is greater variation in regional projections than global projections, with the most severe problems in South Asia and Tropical Africa. These figures also hint that WIM may be considerably more pessimistic than other global models. It should also be noted, however, that model results are highly dependent on time horizon. If one truncates the World 3 standard run at 2000 its projections look optimistic, and similar results arise from truncating the LAWM standard run for Asia at 2000.

Population, economic growth, and disembodied technological progress are exogenous variables in at least three of the six models (see table B-7). All of these variables have important influence on model results, as do their assumptions about the amount of potentially arable land, the cost of developing that land, and the cost of other inputs such as fertilizer, irrigation, and farm machinery. Vital though these factors are to accuracy and reliability, however, there is little agreement among the models on what values they should be assigned. In

some cases this disagreement cannot be resolved because of a lack of statistical evidence or theoretical understanding.

Disembodied Technological Progress

It has become conventional for economists to identify that fraction of income growth (or input cost reduction) that cannot be statistically ascribed to increases in labor, capital, or other inputs as "disembodied technological progress," and to make projections of economic growth under the assumption that rates of technological progress observed in the recent past will continue in the future. This amounts to an assumption that productivity will increase automatically. In most such formulations, the productive contribution of technological progress is very significant: rates above 1 percent per year are common, and it is not uncommon for improved technology to appear to contribute more to economic growth than either labor or capital.

Formulations of this type have been employed in the agricultural sectors of LAWM, UNIOWM, GOL, and MOIRA, but not in World 3 or in some versions of WIM. The specific rates of technological progress assumed in various global models are generally not reported in model documentation, however: LAWM assumes a 1.0-percent annual growth in agricultural productivity, 1.5 percent for capital goods, and rates of either 0.5 or 1.0 percent for other sectors; but analogous figures for UNIOWM, GOL, and MOIRA are not available. Nevertheless, testing shows that model results are quite sensitive to both the presence and the rates of disembodied technological progress. When technological progress is omitted from LAWM, for example, Africa joins Asia in being forced against its land constraints and facing economic collapse. On the other hand, if sufficiently strong assumptions about technological progress are introduced into World 3, the overshoot-and-collapse mode can be eliminated from the model altogether.[21] It should be added, however, that nobody has a very good understanding of technological change; its exclusion or inclusion in global models therefore stems ultimately from hunches, beliefs, and values—not from scientific understanding.

Population

Population growth is exogenous in UNIOWM, GOL, and MOIRA. UNIOWM assumes somewhat higher population growth rates than the two other models, so its optimistic projections of food per capita cannot be ascribed to low population growth rates. MOIRA, on the other hand, assumes rapidly declining rates of population growth, especially for countries whose 1970 growth rates were high, and this may contribute to MOIRA's tendency to become more stable in the last decades of simulation than it is in the first decades. GOL assumes significantly lower population growth rates in the industrialized countries than those projected by the Census Bureau (see app. A). Better linkage in Global 2000 might thus have resulted in less optimistic food trade projections.

Economic Growth

The right side of table B-7 shows the rates of economic growth projected as exogenous drives for the UNIOWM, GOL, and MOIRA. In all three models these projections are used (in combination with the demographic projections) to project income per capita, which in turn is used in projecting demand for agricultural products. The standard runs of UNIOWM and MOIRA assume rapid economic growth in the developing countries (7.2 percent and 7.6 percent per year, respectively). This leads to rapid increases in agricultural demand, due to the fact that demand for food in poor countries is quite income elastic. In UNIOWM, increased demand causes increased production directly, while in MOIRA it causes price increases, which in turn stimulate increased production. When lower rates of economic growth are assumed in MOIRA, prices and production stay low and the food situation improves less rapidly (it even deteriorates, in South Asia). The Global 2000 income growth projections are generally lower, particularly for non-OPEC developing countries, which undoubtedly contributes to the fact that GOL projections of food availability in the LDCs are much more pessimistic than analagous projections in the UNIOWM and MOIRA.

Potential Agricultural Land

MOIRA, World 3, and WIM all use formulations in which the costs of further increases in land development are dependent on the amount of land already under cultivation. A prodigious amount of work went into estimating these relationships for MOIRA, including derivations of absolute maximum dry-matter production potential based on FAO soil maps and plant physiology models.[22] The figures used in World 3 derive from the President's Science Advisory Committee (PSAC) report, *The World Food Problem* (1967), and are likewise based on detailed studies of soil maps and climatological data. The derivation of the figures used in WIM has not been documented.

[21] H. S. D. Cole, op. cit., p. 64.

[22] Linnemann, et al., op. cit., pp. 19-74.

A comparison of the values used in these three models shows that differences between MOIRA and the PSAC/World 3 are relatively minor—PSAC gives South America somewhat more agricultural land, North America slightly less, and Europe quite a bit less. The WIM estimates, however, proved to be markedly lower for all regions except Western Europe, and WIM's estimate of the world's total potentially arable land are only about 70 percent of the MOIRA figures and about 76 percent of those used in World 3. WIM's relatively pessimistic assumptions about land availability, particularly in the developing regions, undoubtedly contributes to its dire predictions of impending famine. However, as shown in sensitivity tests of the World 3 agriculture sector, an increase in potentially available land of 30 percent or more does not change the net outcome of the model—it merely postpones by a few years the date at which scarcity becomes acute.[23]

[23] J. Randers and E. K. O. Zahn, "The Agricultural Sector," in *Dynamics of Growth in a Finite World*, D. Meadows, et al. (eds.) (Cambridge, Mass.: M.I.T. Press, 1974), pp. 339-348.

Other Factors Affecting Reliability and Accuracy

Global agricultural data are often poor, and all models necessarily contain a lot of guesswork. For example, no one has very many or very good economic data on China, nor are there reliable data on the soils (and hence the agricultural potential and costs of agricultural development) in Amazonia. In addition, agriculture will undoubtedly be affected in the coming decades by several trends for which no global model accounts. None of these six models accounts for potential competition between the agriculture and energy sectors for water or land. None takes the global monetary system into account. None looks at the effects of climatic change or increased levels of atmospheric carbon dioxide. Nor does any of them examine the agricultural consequences of unusally bad weather or a serious destabilization of oil and gas supplies.

APPENDIX C

Energy Projections[1]

Introduction

The future availability and price of natural resources are crucial variables in long-range projections of world economic development. Energy supply and demand in particular affect not only industrial production but also agriculture, transportation, and general living conditions. As a result, the findings and conclusions of these five global modeling studies are significantly influenced by their treatment of the global energy system and their assumptions about future energy trends. Some of the models do not address energy specifically, or in detail, and others merely assume that energy will not be a constraint within their restricted time horizons.

In general, those models that include a finite resource stock tend to show that depletion will raise prices, slow production, and dampen global economic growth; in short, resource constraints make them susceptible to economic collapse. Even the most optimistic findings, however, suggest that the world faces a difficult transition away from dependence on oil. Coal, nuclear, and solar power are offered as the principal alternatives for the future energy system. The accuracy and reliability of these projections are also influenced by their assumptions about population and economic growth, potential technological progress in extraction and conservation, the potential for substitution and alternative sources, and the future political and economic behavior of both producers and consumers.

Purposes, Structures, and Findings

World 3

Although *The Limits to Growth* is sometimes said to have "predicted" the energy crisis of the 1970's, the World 3 model itself does not specifically address future trends in energy supply and demand. The purpose of the model is to describe the world as a general system rather than to predict its parts in detail, so energy resources—petroleum, natural gas, and coal—are lumped together with 16 other raw materials (primarily metals) in a single category called "nonrenewable resources." The authors cite U.S. Government estimates showing total reserves of individual resources ranging from 7 to 5,100 years, but they assume that, *on average*, there are about 250 years worth of nonrenewable resources at 1970 consumption levels. They also assume, however, that the quantity of resources consumed per capita is a fixed function of average income per capita, and that continued population and economic growth will lead to a 4-percent growth rate in total world resource consumption. Consequently, this 250-year reserve would be completely used up by about 2040 if growth continues unabated. In addition, the model assumes that the cost of obtaining resources will rise dramatically once 50 percent of the reserves have been depleted, due to declining resource quality and increasing transportation costs.

The standard run of World 3 demonstrates the consequences of this combination of assumptions for the behavior of the nonrenewable resource sector and for the entire world system (fig. C-1). Rising population, combined with rising industrial production per capita, results in the rapid depletion of resources and an equally rapid increase in the costs of obtaining the resources. As more and more capital is diverted from agricultural and industrial production to the obtaining of raw materials, per capita food and industrial output alike begin to decline. This leads eventually to mass starvation and the collapse of the world economic system.

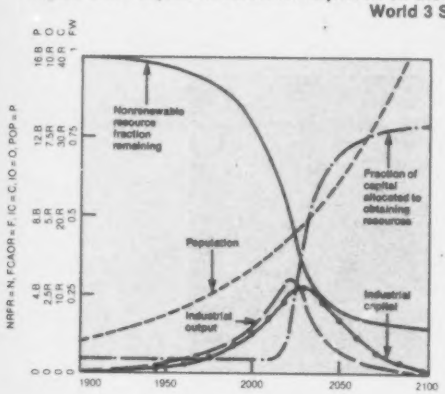
Sensitivity tests conducted by the authors of World 3 indicate that the general behavior of the nonrenewable resource sector and of the integrated world system are not particularly sensitive to their assumptions about resource reserves, consumption rates, or extraction costs.

- If reserves are set at twice their initial value, the collapse is delayed by only 15 years (fig. C-2).
- A tenfold increase in initial reserves will eliminate resources as a constraint to growth—at least before 2100—but the general behavior of the world system remains unchanged. In this case, persistent pollution causes a decline in production followed by starvation and a decline in population (fig. C-3).
- Improved extraction technologies, by reducing the short-term cost of obtaining virgin materials, would eliminate the economic incentives for conservation and substitution. These technologies could delay the collapse a few years, but they would cause a faster depletion of resources and a sharper eventual decline in industrial output (fig. C-4).
- Improved conservation technologies, sufficient to reduce per capita consumption by a factor of four, allow much higher industrial output and postpones its decline for about 40 years, but they cannot prevent eventual collapse (fig. C-5).

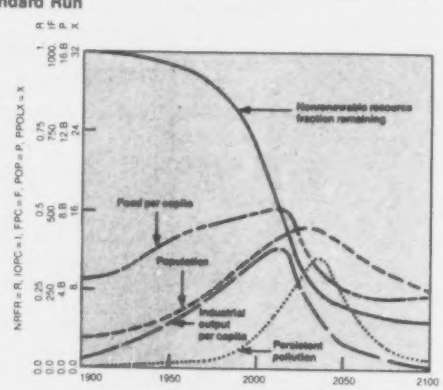
The only model run that succeeds in postponing the collapse beyond 2100 is based on the combination of

[1]The following material is based in part on the draft working paper, "The Role of Energy in the Global System," by Paul Werbos, Office of Energy Information Validation, Energy Information Administration, U.S. Department of Energy.

Figure C-1.—Impact of Resource Depletion on the Nonrenewable Resource Sector and Integrated Model, World 3 Standard Run



Run 5-1: standard run for the nonrenewable resource sector.

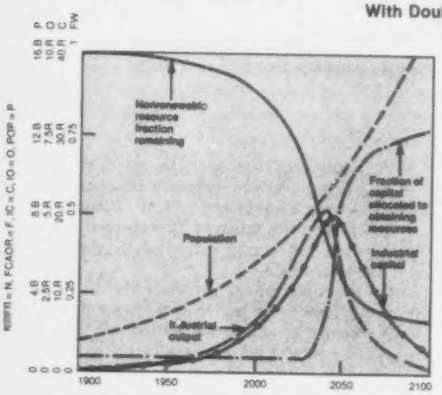


Run 7-6A: World 3 reference run.

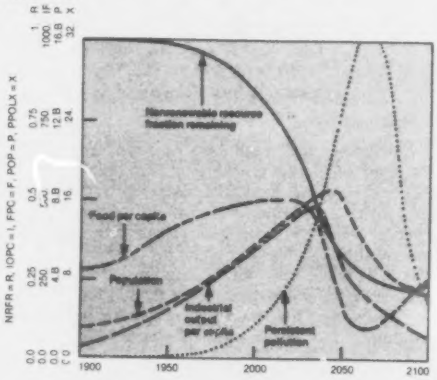
This is the World 3 reference run, to be compared with the sensitivity and policy tests that follow. Both population POP and industrial output per capita IOPC grow beyond sustainable levels and subsequently decline. The cause of their decline is traceable to the depletion of nonrenewable resources.

SOURCE: *Dynamics of Growth in a Finite World.*

Figure C-2.—Behavior of the Nonrenewable Resource Sector and Integrated World 3 Model With Doubled Reserves



Run 5-2: behavior of the sector with double the initial value of nonrenewable resources.

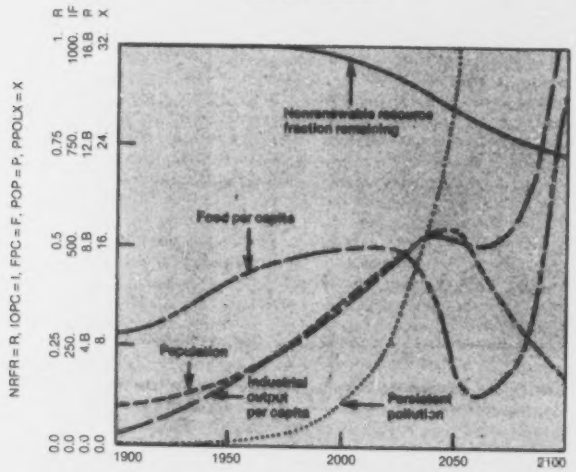


Run 7-7: sensitivity of the initial value of nonrenewable resources to a doubling of NRI.

To test the sensitivity of the reference run to an error in the estimate of initial nonrenewable resources, NRI is doubled. As a result, industrialization continues for an additional 15 years until growth is again halted by the effects of resource depletion.

SOURCE: *Dynamics of Growth in a Finite World.*

Figure C-3.—Behavior of the World 3 Model When Initial Resource Reserves Are Increased Tenfold



Run 7-8: sensitivity of the initial value of nonrenewable resources to a tenfold increase in NRI.

The initial value of nonrenewable resources NRI is increased by a factor of 10, to a value well outside its most likely range. Under this optimistic assumption, the effects of nonrenewable resource depletion are no longer a constraint to growth. Note that there is no dynamic difference in this run between setting resources at 10 times their reference value or assuming an infinite value of resources. However, population and capital continue to grow until constrained by the rising level of pollution.

SOURCE: *Dynamics of Growth in a Finite World.*

cost-reducing and resource-conserving technologies with zero population growth after 1975 (fig. C-6). Even this run, however, shows the beginning of the characteristic rise in the amount of capital that must be allocated to obtain resources—the collapse of the economic system, although delayed beyond the model's time horizon, will undoubtedly still occur in the 22d century. No test was performed to measure the model's sensitivity to the assumption that industrial output per capita will continue to increase exponentially as it has in the past.

World Integrated Model (WIM)

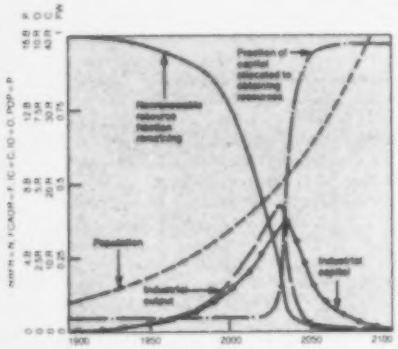
WIM is both more detailed and more flexible in its treatment of energy resources than World 3, and it has been used extensively for testing alternative energy futures. WIM specifically represents both the supply and the demand for five different energy sources—oil, gas, coal, hydroelectric, and nuclear—within each of its 10 or more geographical regions.[2] The model also represents energy trade between regions, a significant advantage in modeling a world system where some 110 nations import over two-thirds of their energy needs and 90 percent of all oil supplies move through the international trade network.[3]

WIM's structural equations reflect the assumption that rising oil prices will lead to both conservation and the development of alternative sources of energy. Investment in energy development is partially controlled by price, which in turn is determined by supply and demand. The model also assumes that oil will cover a declining portion of total world energy demand after

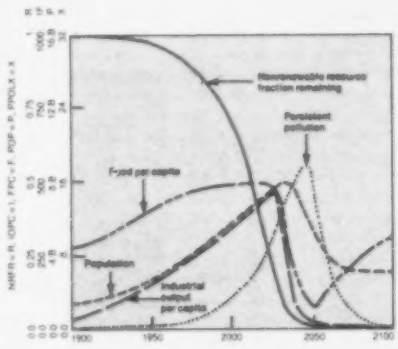
[2]The fifth category, "nuclear energy," also includes solar energy and other capital-intensive alternatives. Source: Command and Control Technical Center (CCTC), *World Integrated Model Multilevel Hierarchical Theoretic Concepts*, CCTC Technical Memorandum TM 197-79 (Washington, D.C.: U.S. Defense Communications Agency, June 15, 1979), pp. 1-17.

[3]M. D. Mesarovic and E. Pestel, *Mankind at the Turning Point* (New York: Dutton, 1974), p. 180.

Figure C-4.—Impact of Cost-Reducing Extraction Technologies on the Nonrenewable Resource Sector and Integrated World 3 Model



Run 5-3: the effects of cost-reducing technologies on the behavior of the nonrenewable resource sector.

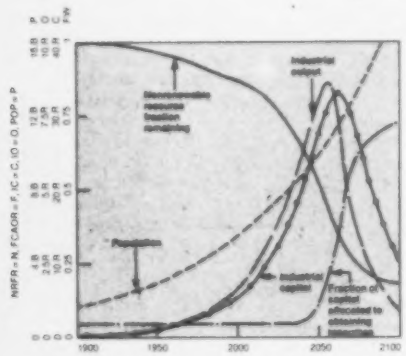


Run 7-12: improved resource exploration and extraction technologies.

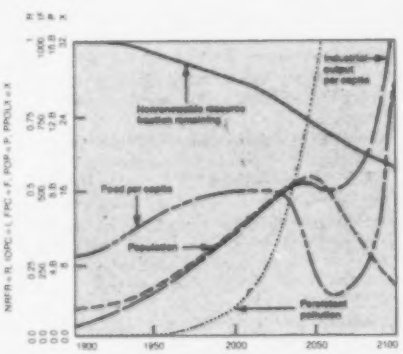
The implementation of improved resource exploration and extraction technologies in 1975 is modeled by lowering the capital cost of obtaining resources for industrial production. This policy allows industrial production to continue growing for a few more years than in the reference run, but it is ineffective in avoiding the effects of resource depletion.

SOURCE: *Dynamics of Growth in a Finite World.*

Figure C-5.—Impact of Resource-Conserving Technologies on the Nonrenewable Resource Sector and Integrated World 3 Model



Run 5-4: the effects of resource-conserving technologies on the behavior of the nonrenewable resource sector.

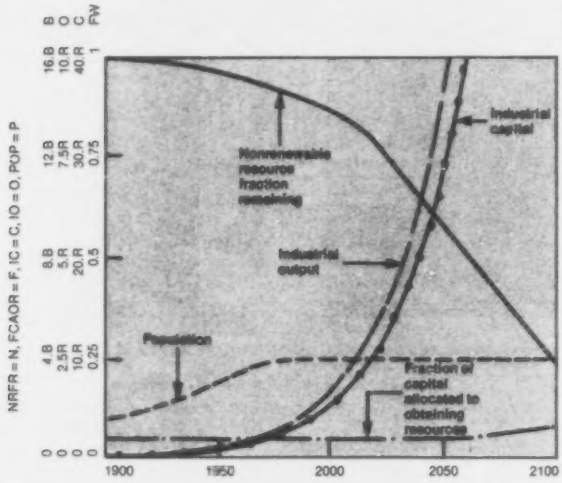


Run 7-13: recycling technologies.

The advances in resource exploration and extraction technologies of Run 7-12 are supplemented by an improvement in recycling technologies that reduces per capita resource usage by a factor of eight in 1975. That policy removes the constraining effects of resource depletion and allows population and capital growth to continue until checked by persistent pollution.

SOURCE: *Dynamics of Growth in a Finite World.*

Figure C-6.—Combined Impacts of Zero Population Growth, Resource Conservation, and Improved Extraction Technologies on the Behavior of the World 3 Nonrenewable Resource Sector



Run 5-5: the effects of zero population growth and advanced technological policies on the behavior of the nonrenewable resource sector.

SOURCE: *Dynamics of Growth in a Finite World*

1990, and that substitution between energy sources will be based largely on cross-price elasticities. Consequently, although oil and oil substitutes are the most binding resources in WIM, energy supply appears to be constrained less by absolute scarcity than by the speed with which substitutes can be developed—energy is an economic and engineering problem, rather than a physical one.[4]

For use as a policymaking tool, the model provides "scenario variables" or "policy levers" with which users can test the consequences of nonmarket pricing behavior by producers or shifting patterns of substitution by consumers.[5] In general, the model runs suggest that cooperation would benefit both producers and consumers and would also ease the transition away from oil, and that continued long-term economic growth may be possible under either of two alternatives: the rapid and widespread deployment of breeder reactors; or the construction of vast "solar farms" and hydrogen plants in the deserts of the Middle East.

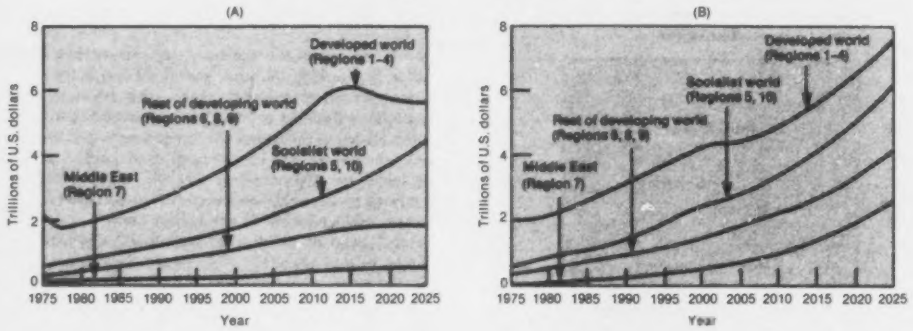
The world oil crisis is a major focus of the many scenarios reported in *Mankind at the Turning Point*. In the first pair of computer runs, the model was used to demonstrate the long-term economic benefits of an "optimal" oil pricing policy (fig. C-7). Continuation of low oil prices would encourage overexploitation and rapid depletion, discourage the development of substitutes, and lead to major dislocations in the developed regions when reserves are exhausted. Both exporters and importers would fare better under an "optimal price scenario," in which the real price of oil rises 3 percent annually until it reaches an optimal level (about 50 percent above the initial price of $13.50/barrel, as determined in a separate analysis), at which level it stabilizes thereafter. Optimal oil pricing is assumed in a second set of computer runs that indicates that both exporters and the developed regions benefit under scenarios in which the flow of oil from the Middle East is unimpeded and international energy trade is "governed solely by the economic forces without undue interference from the political level" (fig. C-8).[6] All of these runs, however, project a transient world oil deficit between

[4] P. VanderWerf, "Energy," in *The Global 2000 Report to the President* (Washington, D.C.: Council on Environmental Quality and Department of State, 1980), vol. 2, p. 618.

[5] CCTC, op. cit., pp. 2-17.

[6] Mesarovic and Pestel, op. cit., p. 112.

Figure C-7.—Comparison of Long-Term World Development for World Integrated Model "Fixed Low Oil Price" Scenario and World Integrated Model "Optimal Oil Price" Scenario


(A)
(B)
Trillions of U.S. dollars
Year
Developed world (Regions 1–4)
Rest of developing world (Regions 6, 8, 9)
Socialist world (Regions 5, 10)
Middle East (Region 7)
1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025

Cheap energy in the form of oil has been a prime fuel for the unprecedented growth of the world economy in the 1950's and 1960's. The dramatic increase in oil prices in 1973 was viewed as a catastrophe. However, computer analysis of our world system model indicates that the continuation of what amounts to overexploitation of oil, spurred by an unreasonably low price, would lead to major dislocations because of the exhaustion of reserves and the lack of motivation to develop substitutes in time. Pursuance of short term objectives would lead to major dislocations in the long run (see A). A much more beneficial development for all concerned results from the "optimal price scenario" in which the price is gradually increased up to the "optimum" level. Such a policy would bring in the substitutes in a more regular fashion while prolonging the reserves. Both exporting and importing regions would fare better (see B). It is only by taking a global and long term view that such a course of development, most beneficial to all concerned, can be identified.

SOURCE: *Mankind at the Turning Point.*

1997 and 2002 and a severe, persistent deficit beginning around 2020; substitutes or alternative sources would be necessary after that date.

One possible energy future, based on nuclear power, has been proposed by some technological optimists. Tests using the WIM "fast-nuclear scenario" raise questions about the short-term feasibility and long-term consequences of this alternative. After testing short-term scenarios based on Herman Kahn's *The Next Two Hundred Years*, the authors conclude that:

> It is impossible to design any energy program in Western Europe or Japan which could, over a ten-year period, reduce energy demand and increase production of energy from non-petroleum sources sufficiently to compensate for the loss of the Persian Gulf by 1987. The Hudson report statement regarding the ease of adjustment to a quick disappearance of oil reserves is therefore erroneous.[7]

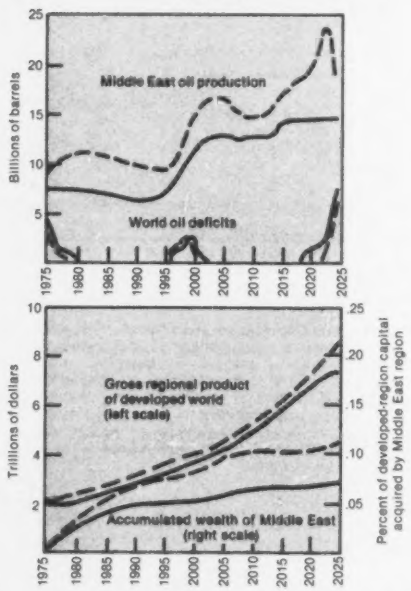
Other WIM tests indicate that the longer term feasibility of the nuclear option is just as questionable. The U.S. Atomic Energy Commission estimated in the early 1970's that nuclear energy would provide 30 percent of the developed world's energy needs by 2000, based on higher demand growth than is now expected. By extrapolating from this figure, the authors found that by 2025 nuclear power would have to provide 60 percent and by 2075 almost 100 percent of all energy needs (see fig. C-9). The social, economic, and security impacts of such a course would be enormous: sole reliance on *fission* nuclear power would require 24,000 fast-breeder reactors worldwide by 2075, which in turn would require the construction of 4 reactors per week for a century and the eventual construction of about 2 reactors per *day* just to replace reactors that have reached the end of their 30-year lifespans, at a cost of $2 trillion per year for replacements alone (see fig. C-10).[8] This scenario would also require the energy sector to process and transport 33 million pounds of plutonium each year; only 10 pounds of this element are needed to construct a nuclear bomb.

Mankind at the Turning Point concludes that an energy future based on nuclear power would be a "Faustian bargain," but this conclusion involves several important assumptions. For one thing, fusion as well as fission could provide the growing nuclear share of energy

[7] B.B. Hughes and M.D. Mesarovic, "Testing the Hudson Institute Scenarios" (Washington, D.C.: U.S. Association for the Club of Rome, September 1979), mimeograph, p. 22.

[8] Mesarovic and Pestel, op. cit., pp. 132-134.

Figure C-8.—Comparison of Middle East Oil Production, World Oil Deficits, Developed-World Gross Regional Product, and Middle East Accumulated Wealth Under Two World Integrated Model Scenarios



Solid line: Middle East withholds oil, imposes ultimate ceiling of 14 billion bbl/yr.
Dotted line: Production and trade governed solely by economic factors.

SOURCE: *Mankind at the Turning Point.*

supply, although fusion power on such a scale would involve similar financial and engineering problems and (at present) even greater technical problems. Another significant factor is the assumed rate of growth for energy demand, which seems unrealistically high in view of subsequent events; in updated projections, higher energy prices and slower demand growth would make the nuclear share—whether fission or fusion—substantially smaller. The authors prefer an energy future that places mid-term reliance on coal and coal-derived synfuels, combined with long-term development of huge "solar energy farms" in the present oil-producing regions. This alternative has not been tested with the model, but it too would involve massive capital and engineering requirements, even with slower energy demand growth. Because of its technical uncertainties (see below), and because it is not based on explicit analysis with WIM, this solar alternative remains speculative.

Latin American World Model (LAWM)

LAWM assumes the nuclear-energy future that WIM rejects, but unlike the other global models it contains no representation of energy or any other resource. The structure of LAWM is based on the assumption that, "for the foreseeable future, the environment and its natural resources will not impose barriers of absolute physical limits" on the satisfaction of basic human needs.[9] The authors base this assumption on two studies conducted independently of the model itself: a survey of currently known reserves of fossil fuels, which found enough oil and gas to last 100 years, and enough coal to last 400 years, at present consumption levels;[10] and an analysis of future production costs for energy, which found that:

> . . . the so-called energy crisis . . . is of a conjunctural character, such as others of similar importance that occurred in the past. And it may be perceived that the main reactions of the system will be to establish a new equilibrium, which, generally speaking, in the long term will not differ from the previously observed trends.[11]

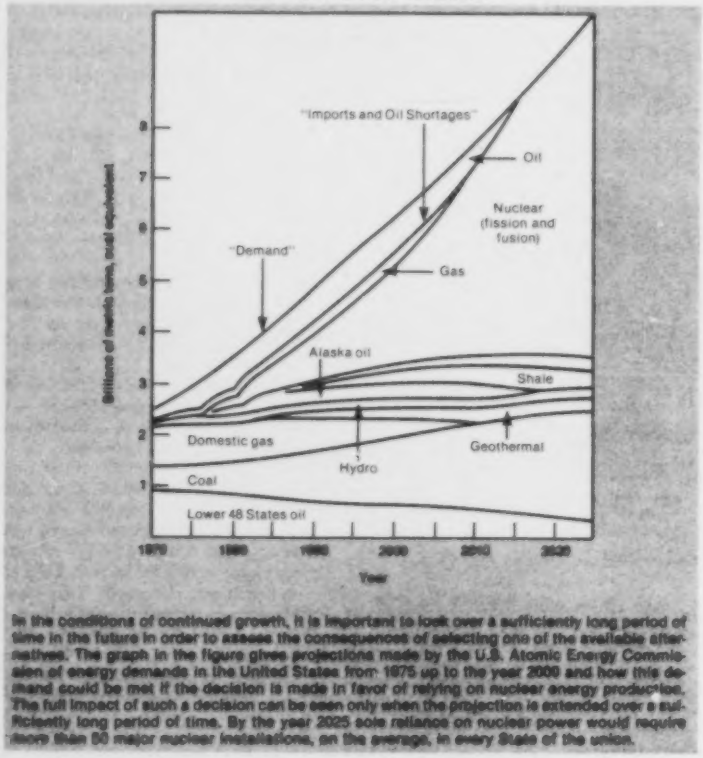
The latter conclusion appears inconsistent with the authors' own reserve estimates, which represent slightly more oil and gas but considerably less coal than those used in World 3 and WIM. However, the authors assert that "the most important fuels for the future are nuclear fuels." They cite predictions that nuclear power will generate 50 percent of the world's electricity by 2000, and, although their own estimate of uranium oxide reserves reflects only 33 years supply even at 1970 levels, they suggest that "a small increase in the price or an advance in technology" will make it economical to extract vast amounts of uranium from granite or seawater.[12] The model itself, however, does not reflect the capital costs or potential technical bottlenecks involved in this nuclear scenario.

United Nations Input-Output World Model (UNIOWM)

The central concern of UNIOWM is to reduce the income gap between the rich and poor nations *before the year 2000*. In order to determine whether U.N. development targets are consistent with the availability of nonrenewable resources, the model projects the levels of production and world trade in six metals and three en-

[9] A. O. Herrera, et al., *Catastrophe or New Society? A Latin American World Model* (Ottawa: International Development Research Centre, 1976), p. 8.
[10] Ibid., pp. 32-33.
[11] Ibid., p. 34.
[12] Ibid., p. 33.

Figure C-8.—Projected U.S. Energy Supply Distribution for World Integrated Model "Fast-Nuclear" Scenario



In the conditions of continued growth, it is important to look over a sufficiently long period of time in the future in order to assess the consequences of selecting one of the available alternatives. The graph in the figure gives projections made by the U.S. Atomic Energy Commission of energy demands in the United States from 1975 up to the year 2000 and how this demand could be met if the decision is made in favor of relying on nuclear energy production. The full impact of such a decision can be seen only when the projection is extended over a sufficiently long period of time. By the year 2025 sole reliance on nuclear power would require more than 50 major nuclear installations, on the average, in every State of the union.

SOURCE: *Mankind at the Turning Point*

ergy sources (oil, gas, and coal) that would be required to support its relatively high rates of population and economic growth. Its major conclusion:

> The problem of the supply of mineral resources for accelerated development is not a problem of absolute scarcity *in the present century* but, at worst, a problem of exploiting less productive and more costly deposits . . . and of intensive exploration for new deposits . . . .[13]

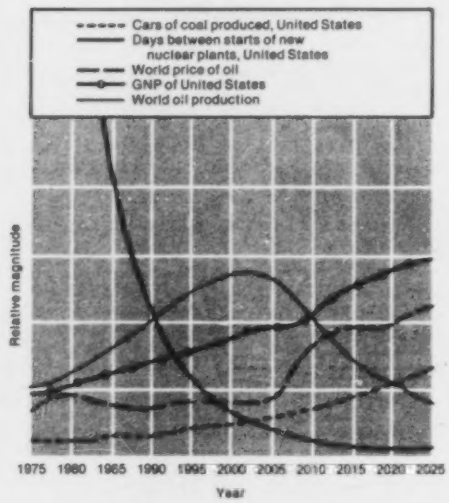
Reserves and prices are determined independently of the model itself, and the amount of each resource required for expansion in each economic sector is adjusted for assumptions about increased efficiency due to technology. Most of these technical assumptions are not reported, although the model does assume 55-percent recycling of all materials, worldwide, by 2000.[14] The model also assumes that all nations will rapidly develop domestic reserves, but that extraction costs will rise as high-grade deposits are exhausted.

The authors project that 77 percent of the world's known petroleum reserves will be depleted by 2000, but their confidence about future energy supplies rests on the world's plentiful reserves of coal, which they "conservatively" estimate at 9 trillion metric tons (roughly the same as World 3). The model assumes "autonomous

[13]W. Leontief, A. Carter, and P. Petri, *The Future of the World Economy: A United Nations Study* (New York: Oxford, 1977), p. 11; emphasis added.

[14]Ibid., pp. 5, 45.

Figure C-10.—Long-Term Consequences of U.S. Energy Self-Sufficiency Under World Integrated Model "Fast-Nuclear" Scenario


Cars of coal produced, United States
Days between starts of new nuclear plants, United States
World price of oil
GNP of United States
World oil production
Relative magnitude
1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025
Year

SOURCE: Systems Research Center, Case Western Reserve University.

substitution" between energy sources, but it does not rely on cross-price elasticities nor does it compute prices endogenously. For example, it assumes that shale oil and gasified coal will replace petroleum and natural gas in North America before 2000, but it also assumes that the price of coal will decline despite a sevenfold increase in the price of natural gas.[15] In addition, UNIOWM assumes a growing substitution of nuclear for conventional fuels in the utility sector, although this assumption is not reported in the documentation.[16]

In all of its many scenarios, UNIOWM projects a tremendous increase in world consumption of minerals and energy between 1970 and 2000. The global demand for petroleum is projected to increase 5.2 times, natural gas 4.5 times, and coal 5.0 times 1970 levels. Rapid industrialization in the developing regions causes them to more than double their share of world energy consumption. The Middle East remains the major net exporter of petroleum, with output projected to rise almost eightfold—a projection that now appears unrealistic in view of subsequent OPEC production decisions. Non-OPEC developing regions, along with Western Europe and Japan, become increasingly dependent on imported petroleum; but the U.S. oil deficit disappears after 1990, apparently due to the development of shale oil and a sudden doubling of domestic coal consumption in the 1990's. Despite anticipated advances in mining technology and industrial efficiency, the percentage of capital stock used in resource extraction increases steadily in all regions, just as it did in World 3.

In the standard scenario, based on the U.N.'s International Development Strategy, the real price of natural gas increases by 656 percent and that of petroleum by 225 percent over the 1970-2000 period; but the price of coal—the most plentiful energy resource—actually declines by 14 percent in constant dollars.[17] In a second scenario based on "more generous" resource endowments, production and consumption levels change very little and extraction costs, although they rise later, are just as high by 2000. The most significant impact of higher reserve estimates is on trade deficits: this scenario reduces the balance-of-payments deficit of the developed regions by 50 percent, but the non-OPEC developing regions, after being better off in 1990, have accumulated greater debts by 2000 than they do in the standard, "conservative" scenario.

In a later policy test conducted for the U.S. Department of Commerce, UNIOWM indicates that aggressive fossil-fuel conservation in developing regions could reduce LDC trade deficits and thereby remove the main economic constraint to Third World development.[18] Such a course would also increase LDC capital requirements and (implicitly) would require an even greater nuclear share to provide adequate energy for continued industrial expansion. In general, the authors find energy to be an economic rather than a physical problem, at least until 2000: internal reform in the LDCs and the creation of a "new international economic order" are the necessary conditions for accelerated development in this century, although the model's restricted time horizon prevents it from examining the sustainability of such growth in the next century.

Global 2000

The energy projections in the *Global 2000 Report* include a variety of short-term and midterm forecasts, based on different methodologies and assumptions, whose purpose is "to define a range of credible futures against which alternative policy options can be tested."[19] The report's estimates of total world reserves

[15]Ibid., p. 65.
[16]A. Carter, private communication, April 1981.
[17]Leontief, Carter, and Petri, op. cit., p. 65, table 61; these projections, like those for production, appear unrealistic in view of subsequent events.
[18]A. P. Carter and A. K. Sim, "An Energy Conservation Scenario for the World Model," prepared for the Bureau of International and Economic Policy, U.S. Department of Commerce, November 1977, p. 2.
[19]J. Pearson, et al., "Energy Projections," in *The Global 2000 Report to the President* (Washington, D.C.: U.S. Council on Environmental Quality and Department of State, 1980), vol. 2, p. 173.

of fuel minerals come from figures prepared by the World Energy Conference, the Congressional Research Service, and the U.S. Geological Survey; but these reserve estimates are not used as inputs to the production or consumption forecasts. The short-term projections (1975-90) were prepared by the Department of Energy's Energy Information Administration (EIA) soon after its creation in late 1977, using two similar computer models: the Project Independence Evaluation System (PIES) for U.S. figures, and the International Energy Evaluation System (IEES) for global figures. The forecasts made for the Global 2000 study use the study's low, medium, and high growth-rate assumptions for population and GNP, but the energy projections were not used as inputs for other sectors; in essence, "GNP is implicitly treated as independent of the energy market."[20]

Both PIES and IEES are equilibrium market simulations, in which producers compete to satisfy short-term world demand and the entire global energy system is assumed to act in such a way as to minimize total costs without regard for the future value of the resources. As a result, both models assume that unlimited world oil supplies will be available at prices (determined outside the models) that rise from $13/barrel in 1978 to $23/barrel in 1990. The models contain detailed representations of the OECD countries and the major fuels, but they contain no representation of resource depletion or political factors and only simplified demand equations for the growing LDC market. The models assume that coal and nuclear will substitute for oil in response to price elasticity, but they impose no limit on the creation of new generating capacity in the utility sector. (The number of new generating plants is determined by expert judgment rather than price, a procedure that may be reasonable for forecasts through 1990: the lead time for developing new productive capacity is so long that current investment plans are a good guide to what will happen in the next 10 years.)

EIA was unwilling to extend its IEES forecasts beyond 1990, and Global 2000's midrange energy projections (1985-2000) are based instead on four different studies representing diverse philosophical and methodological approaches, as well as different assumptions about future demand growth and fuel substitution (see fig. C-11):

- the Workshop on Alternative Energy Strategies study, based on estimates from independent national experts, predicts global supply-demand "gaps" of 15 million to 20 million barrels of oil per day by 2000 and examines the consequences of choosing either nuclear or coal as the major replacement;
- the World Energy Conference study, after examining different assumptions about world oil reserves and recovery rates, predicts that global production will peak at a ceiling of 82 million to 104 million barrels per day around 1990, and emphasizes coal and hydropower as replacements when oil supply falls short of demand;
- the Stanford Research Institute (SRI) model of the U.S. energy market through 2020 (see below), which foresees a relatively plentiful energy supply based on coal but assumes perfect consumer foresight about future shortages and prices; and
- a Brookhaven National Laboratory/Dale Jorgenson Associates study of the U.S. energy market, which emphasizes conservation and coal as well as the development of nuclear and renewable sources.

In general, to the degree that these diverse projections can be compared, Global 2000 suggests that a rapid increase in the supply of energy will be needed through the end of the century, even with a declining rate of economic growth. Demand growth will be moderated only by price increases, and significantly higher oil prices will be needed to encourage substitution. Because petroleum production capacity is increasing more slowly than demand, a supply-constrained market is likely before 1990. Furthermore, because the rate of petroleum reserve additions is falling, world production is likely to peak between 1990 and 2010 and gradually decline thereafter. As a result, "a world transition away from petroleum dependence must take place, but there is still much uncertainty as to how this transition will occur."[21]

The findings suggest a considerable potential for coal and natural gas beyond 2000, but the short-term projections indicate that nuclear power will expand far faster than any other source, particularly if oil prices continue to increase. The potential contribution of solar and other renewable sources is rather limited at best. However, there does appear to be a substantial long-term potential for "aggressive, conservation-induced reductions in energy consumption."[22] The alternative energy systems examined in the different studies indicate that options do exist, however limited, and that current decisions about the future fuel mix will have increasingly significant impacts after 2000.

Other Energy Projections

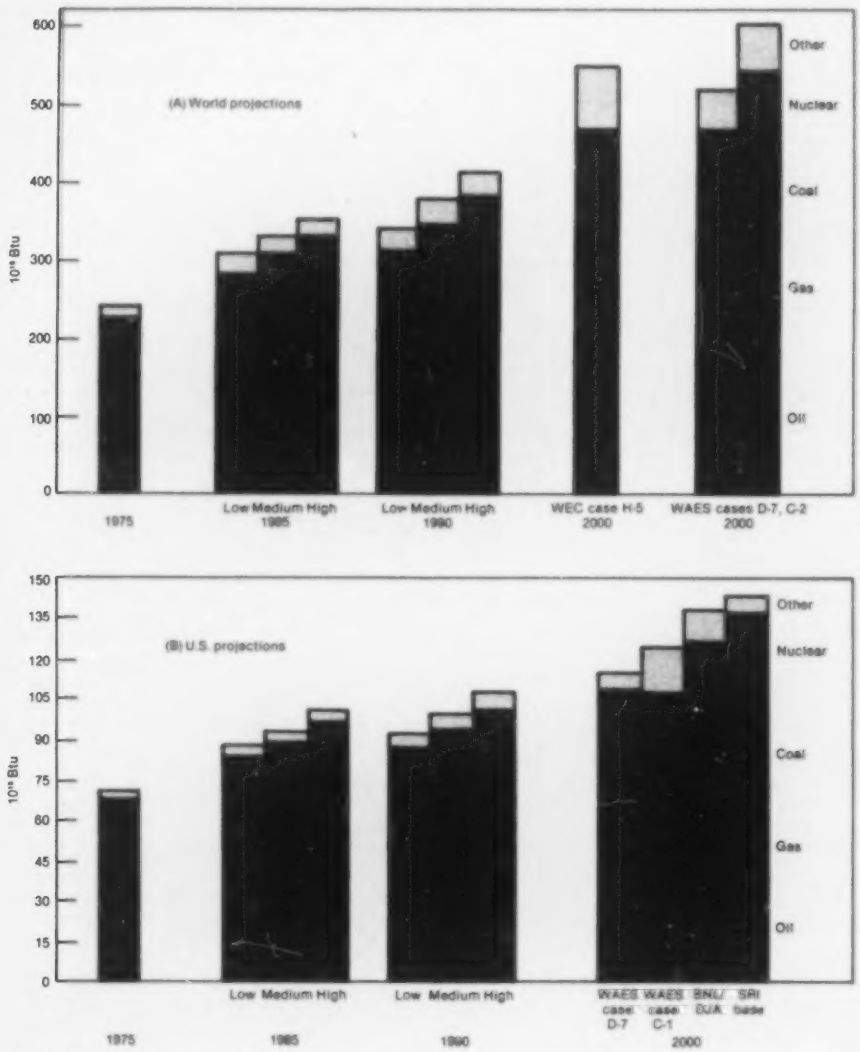
Concurrently with its PIES/IEES short-term global projections, EIA also produced a set of long-term (1978-2020) energy projections for the United States using the Long-term Energy Analysis Program (LEAP), an up-

[20] VanderWerf, op. cit., vol. 2, p. 571.

[21] *The Global 2000 Report to the President*, vol. 1, p. 27.

[22] Pearson, et al., op. cit., p. 161.

Figure C-11.—Comparisons of Global 2000 Projections of World and U.S. Energy Consumption and Supply Mix, 1975–2000



SOURCE: *The Global 2000 Report to the President.*

dated version of the SRI energy model (see above).[23] This forecast, which was not reported in the *Global 2000 Report*, describes the energy requirements for continued economic growth in the United States during a transition from oil to coal and nuclear power. It assumes the rapid development of shale oil and synfuels to replace oil imports, as well as an ambitious level of energy conservation: a 48-percent reduction in the energy-consumption-to-GNP ratio, based on improvements considered possible on the basis of known technologies, with almost no increase in residential consumption and most of the demand growth coming in the industrial sector. It also assumes that the rate of real GNP growth will decline to 2.4 percent by 1995. Despite these assumptions, the SRI model's projections would require U.S. coal production to triple by 2000 and reach 5 times present levels by 2020; nuclear power would increase eightfold by 2000 and reach 16 times present levels by 2020. This vast expansion is required partly to satisfy growing industrial demand, but primarily because coal and nuclear must grow from 23 percent of primary energy to 72 percent in order to replace depleted U.S. oil and gas. (This energy supply mix corresponds roughly to the "fast-nuclear scenario" that was tested with WIM; see figs. C-9 and C-10, above).

EIA's Office of Energy Information Validation has conducted an evaluation of this 1978 forecast, and their report cites a number of factors that might modify these projections:[24]

- statistical studies of U.S. oil reserves suggest that there may be only half as much domestic oil available as previously estimated by the U.S. Geological Survey and assumed in the forecast;
- recent studies show that the actual costs for shale oil and synfuels may be two to four times greater than earlier engineering estimates, and that there are severe physical constraints on the development of a massive synfuels industry;
- the forecast assumes that extraction costs for coal and uranium will not increase significantly over time due to depletion or scale, and that environmental consideration will not impede the development of these industries;
- the forecast does not address the capabilities of the relevant industries and therefore fails to consider potential bottlenecks and constraints, including the need to build up the U.S. railroad system, a potential shortage of engineers and deep-seam miners, the risk aversion and capital constraints of potential consumers, and the potential efforts of State governments to prevent rapid expansion in the West; and
- more recent data, and more realistic technical assumptions, suggest that electric cars can capture 50 percent of the U.S. personal-transportation market by 2000—despite optimistic oil prices and moderate consumer prejudice—if automobile companies can acquire enough capital to keep up with the potential market.

These and other problems are discussed in more recent forecasts by EIA, which continues to refine, validate, and expand its energy modeling capability; but despite a number of structural changes in the models, the 1980 forecasts are based on many of the same assumptions as the Global 2000 projections.[25] Midterm global energy projections (1975-95) now come from an improved version of the IEES model that incorporates the annual oil production *capacity* forecasts provided by DOE's Office of International Affairs and the oil *price* forecasts generated by the Oil Market Simulation (OMS) Model. OMS assumes that OPEC will raise oil prices only when world demand requires them to use almost all of their annual production capacity, and it also reflects lower rates of economic growth. Oil prices are projected to reach $50/barrel in constant mid-1979 dollars by 1995, with almost no increase in oil consumption between now and then. This projection assumes, however, that all OECD nations will reach their official conservation targets and that higher prices will lead to further substitution away from oil. Coal is projected to provide a slightly larger share of total energy demand; nuclear projections are lower due to lower estimates of the speed with which new reactors will be built.

Long-term U.S. energy projections (1975-2030) now come from LEAP, a descendent of the SRI model that EIA used in 1978. LEAP still assumes an unlimited supply of oil imports, at the OMS/IEES world price, but it predicts that the United States will require far fewer imports over the next 40 years. This is due in part to conservation and in part to massive deployment of shale oil and synfuels: U.S. oil consumption is cut in half between 1978 and 2020; and of the remaining demand for liquid fuels, coal-based synthetics provide 50 percent, shale oil 27 percent, and conventional oil only 23 percent. This assumes that the goals of the Synthetic Fuels Corp. (1.5 million barrels per day by 1990 and 3.0 million by 1995) will be met or exceeded, and that there will be virtually no constraints on the expansion of the synfuels industry after 1995. This projection also accepts with little modification the current engineering estimates of synfuel costs; sensitivity tests, using capital costs twice as high as these estimates, lead to an in-

[23]Energy Information Administration, *Annual Report to Congress 1978* (Washington, D.C.: Department of Energy, 1979), vol. 3.

[24]Office of Energy Information Validation, *Analysis Quality Report: 1978 Long-Term Forecasts and Methodology* (Washington, D.C.: Energy Information Administration, 1981).

[25]Energy Information Administration, *1980 Annual Report to Congress* (Washington, D.C.: Department of Energy, 1981), vol. 3.

crease in U.S. oil imports through 2020. LEAP also assumes an upper limit to the net contribution of renewable energy sources (hydro, wind, biomass, small-scale solar, etc.) of about 6 percent of U.S. demand in 2020.[26]

Strengths and Weakness of Energy Projection Techniques

All of these models are generalized analytic tools that can accommodate a variety of assumptions and serve a variety of applications. Some of them have features that limit their usefulness in examining the future of the global energy system, but these features were usually appropriate to the models' original purposes. World 3, for instance, was intended to give a generalized description of the long-term behavior of the entire global system except agricultural land; as a result, it treats energy only as part of a highly aggregated "nonrenewable resources" sector and makes no specific projections of energy supplies or prices. LAWM explicitly excludes all resource constraints except agricultural land; it assumes that energy and other resources will be available and concentrates instead on how they should be allocated in order to satisfy basic human needs. UNIOWM and Global 2000, because of their shorter time horizons and the absence of resource depletion in their structures, are ill-suited for examining the long-term effects of resource depletion. In addition, UNIOWM concerns itself primarily with development targets and trade balances—although it treats the energy sector in detail, it does little more than tabulate resources as they are consumed in meeting those goals. Global 2000's IEES projections represents major producers and consumers of oil in detail, but they contain considerably less detail for other fuels or for the rapidly growing Third World market. Furthermore, Global 2000's energy projections do not interact with other sectors and therefore do not reflect competing demands for energy resources. WIM strikes a balance between detail and generality, and its policy levers provide more flexibility than the other models for testing alternative energy futures and different producer and consumer behavior. Because of its complexity and lack of documentation, however, the value of WIM's conclusions may not have been fully tested or understood.

Factors Affecting the Accuracy and Reliability of Energy Projections

These differences in purpose and technique have an influence on the projections generated by the different models, but the accuracy and reliability of these projections are also affected by a number of factors and uncertainties on which there is presently little general agreement or understanding. Among these factors are the following:

- total resource reserves and future prices;
- population and GNP growth rates;
- conservation;
- Third World energy choices;
- development bottlenecks; and
- future energy breakthroughs.

Total Resource Reserves and Future Prices

Table C-1 shows the estimates of total world reserves of conventional energy resources on which the different models are based. There is little agreement among the models on the size of these reserves or how they should be measured, and even less agreement on the costs of extracting them. In general, however, those models that consider prices show that lower grades and unconventional sources will become available as prices rise. Extraction cost will be higher for these low-grade deposits, however, and recovery rates will be significantly lower. Consequently, a steadily larger percentage of capital will have to be allocated to obtaining resources, leaving less capital for investment in other sectors. Improvements in extraction and processing technologies might modify this trend, but recent studies have shown that capital costs for shale oil and coal synfuels are likely to be higher rather than lower than previously estimated.

Several of the models predict an energy future based on abundant reserves of coal, but estimated total reserves of coal have increased little since 1913, when they were estimated at 8,000 billion metric tons.[27] Of the 9,000 billion metric tons now generally agreed upon, 50 percent or less is recoverable with current techniques, and two-thirds are reserves claimed by the U.S.S.R. that some experts treat with skepticism. Until recently, however, there has been little incentive for further exploration; new deposits may soon be discovered due to renewed interest in coal.

[26] For further assessment of the technologies and assumptions involved in these projections, see the following OTA reports and technical memoranda: *Nuclear Proliferation and Safeguards*, OTA-E-48 (June 1977); *Gas Potential From Devonian Shales of the Appalachian Basin*, OTA-E-57 (November 1977); *Enhanced Oil Recovery Potential in the United States*, OTA-E-59 (January 1978); *A Technology Assessment of Coal Slurry Pipelines*, OTA-E-60 (March 1978); *Application of Solar Technology to Today's Energy Requirements*, OTA-E-66 (June 1978); *The Direct Use of Coal: Prospects and Problems of Production and Combustion*, OTA-E-86 (April 1979); *Gasahol: A Technical Memorandum*, OTA-TM-E-1 (September 1979); *The Future of Liquefied Natural Gas Imports*, OTA-E-110 (July 1980); *Energy From Biological Processes*, OTA-E-124 (July 1980); *World Petroleum Availability 1980-2000: A Technical Memorandum*, OTA-TM-E-5 (October 1980); *Nuclear Powerplant Standardization: Light Water Reactors*, OTA-E-134 (April 1981).

[27] H. S. D. Cole (ed.), *Models of Doom: A Critique of the Limits to Growth* (New York: Universe Books, 1973), p. 98, on the other hand, these reserves have seemed so large relative to expected demand that there has been little incentive for increased exploration.

Table C-1.—Energy Resource Reserves as Described by Five Global Modeling Studies

Global model	Year	Petroleum (billions of barrels)	Natural gas (trillions of ft^3)	Coal (billions of metric tons)	Uranium oxide (millions of metric tons)
World 3	1972	630 ident[a] 1,200 hyp/spec[b]	1,000 ident 10,000 hyp/spec	8,600 ident 8,600 hyp/spec	N/A
WIM	1974	667 proven	285 proven 2,300 ultimate[c]	4,200 recoverable 8,400 total[d]	Implicitly unlimited
LAWM	1976	1,800 total	103 total	9,640 total	0.76 @ $10/lb; practically unlimited @ $20/lb
UNIOWM	1977	1,555 total	N/A	9,080 total	N/A
Global 2000	1978	646 proven 2,100 total	2,520 proven 5,984 hyp/spec	786 proven 12,682 total	1.661 @ $10-$35/lb 2.794 additional at higher prices

N/A = not available.
[a]Identified reserves include both proven and inferred reserves, including deposits that are currently subeconomic.
[b]Hypothetical resources include undiscovered deposits in known districts; speculative resources include undiscovered deposits in districts not presently known to contain deposits.
[c]Ultimately recoverable reserves; total reserves greater.
[d]Assuming that 50 percent of total is recoverable.

SOURCE: Office of Technology Assessment.

The rate at which new petroleum reserves are being discovered, on the other hand, appears to be falling. In addition, many geologists are pessimistic about the prospects for discovering vast new reserves of natural gas at greater depths than have been explored thus far.

There is as yet no indication of diminishing returns in uranium exploration. Current reserves (including speculative reserves at much higher prices) represent less than 50 years of total world energy supplies at current consumption levels (assuming the use of conventional nuclear reactors), although with breeder reactors these reserves would last far longer. Technologies for extracting huge amounts of uranium from granite or seawater remain speculative, and DOE has at times taken the position that uranium is scarce enough to justify the deployment of the breeder reactor.[28]

Finally, none of the models deals with potential reserves of lithium. Despite the LAWM team's confidence that fusion power will solve the world's long-term energy problems, successful development and widespread deployment of this technology remains speculative (see below).

Population and GNP Growth Rates

Appendix A shows that there is general agreement among the projections of world population in 2000, however much the projections differ in the longer term. There is far less agreement among the models on future rates of economic growth. Both factors influence the energy projections, although the effect of GNP projections is somewhat greater.

The standard run of World 3 assumes that population will continue to grow exponentially. It also assumes that the recent rate of world economic growth, 1.7 percent per year measured in real GNP per capita, will also continue through 2000. These two factors quickly force the model against its resource limits, and the global economic system collapses sometime after 2010 due to rising extraction costs. Sensitivity tests indicate that policies designed to slow population growth or limit industrial expansion could delay (but not prevent) this collapse. Critics have claimed, however, that World 3 underestimates the ability of the free-market system to anticipate and thereby prevent a possible catastrophe, although they have not explained how it would be possible to prevent such a catastrophe in the absence of specific new energy sources.[29]

UNIOWM assumes a slightly faster population growth and a much higher growth rate for gross product per capita—3.0 percent per year even in its most pessimistic "business as usual" scenario, and as high as 6.0 percent per year for the LDCs in other scenarios. The model does not examine the long-term sustainability of these growth rates, however, and the principal reason why UNIOWM does not predict a catastrophe is that it stops at 2000.

LAWM's population projections are higher still, particularly in the longer term, and its optimization procedures impose high investment rates that lead to economic growth rates of 4.0 percent per year for the devel-

[28]U.S. Atomic Energy Commission (USAEC), *Proposed Final Environmental Statement: Liquid Metal Fast Breeder Program* (Washington, D.C.: National Technical Information Service, 1974).

[29]Cole, op. cit., p. 66.

oped regions and up to 6.0 percent for the LDCs through 2000, gradually declining thereafter to 2.0 and 3.0 percent, respectively. These growth rates do not lead to an energy-related catastrophe because LAWM contains no representation of resource availability.

WIM assumes relatively ambitious population control in many of its scenarios. Even so, it shows that population will not stabilize before 2050 under the best of conditions. Economic growth varies considerably among scenarios, but in at least one policy test the economic growth rate (supported by investment aid from developed nations) remains at 7.0 percent in Latin America and 8.2 percent in South Asia through 2025.

Global 2000's short-term projections test three different sets of population and GNP growth assumptions, in order to illustrate a range of possible futures. Economic growth rates are highest for OPEC and medium-income LDCs, somewhat lower for the developed nations, and lowest for the low-income LDCs and Communist bloc. In all cases, economic growth slows significantly after 1985.

Conservation

Total demand for energy can be represented as the product of three variables: population and GNP per capita (see above), and the ratio of energy consumption to GNP. Conservation can reduce this latter ratio (and thus the total demand for oil and energy at any given level of population and GNP per capita) in either of two ways: 1) by improving the efficiency with which energy is used (e.g., through residential insulation or improved industrial machinery); or 2) by improving the way in which the overall energy system matches energy sources with particular end uses (e.g., a large-scale coal or nuclear generator is more appropriate to the energy needs of a major industrial city than to those of a rural village, which might well be better served by a small-scale wind, hydro, or solar source). Biomass, dispersed solar, and other small-scale alternatives can contribute to the second form of conservation, but conservation of conventional fuels will depend primarily on the response of large-scale industrial and utility consumers.

Many economists believe that higher prices are an efficient mechanism for inducing this kind of conservation, and economic models generally assume that demand will fall in response to future price increases to the same degree that it has in the past. For example, pre-embargo studies of energy demand in the United States generally showed little responsiveness to price: when prices were low, other variables (such as the price of automobiles or new capital equipment) are more important to consumers than energy costs. As prices first began to rise rapidly, there was a large initial demand response due to "housekeeping" conservation and other simple measures, but the long-term response was expected to be slower due to the slower conversion to more efficient automobiles and capital equipment.

However, the response to the 1979 oil price hike suggests that long-term elasticity will be greater than many people had expected. Conservation has been greater—and demand growth slower—than was previously foreseen, even when the effects of economic slowdown are eliminated. In addition, some economists claim that economic models based on the United States do not reflect the full global potential for long-term conservation through more efficient capital equipment.[30] Other studies, however, have shown that technological progress in some critical industrial sectors requires an increasing use of energy per unit of output.[31]

The World 3 standard run assumes that resource consumption per capita will continue to be a fixed function of GNP per capita. This assumption implicitly rejects any significant potential for conservation and—although reasonable when the results were published in 1972—it gives the standard run a pessimistic bias that has been contradicted by subsequent events. However, World 3's "recycling" run (fig. C-5) does show that conservation, in combination with improved exploration and extraction technologies, can have a significant impact on resource depletion.

WIM, published after the 1973 embargo and price hikes, does assume some conservation in response to higher prices. In the case of oil, a 1.0-percent increase in price is converted into a direct decrease of 0.225 percent in consumption, plus additional decreases due to substitution. The authors conclude, however, that even optimistic assumptions about conservation will not prevent a substantial increase in total energy demand—the world will need to develop alternative sources, either nuclear or solar.[32]

LAWM assumes that the global energy system will make more efficient use of different energy sources in the future, and that technological progress will increase the productivity of the capital goods sector by 1.5 percent per year (a rate that would double the output-to-input ratio in 47 years). For the most part, LAWM's optimism about the availability of energy is based not on conservation but rather on unlimited supplies of nuclear power, including the deployment of fusion technology within 50 years.

UNIOWM also assumes that technological progress will change the energy requirements of every sector. The documentation does not reveal, however, the pre-

[30] R. S. Pindyck, "The Characteristics of Demand for Energy," in J. C. Sawhill (ed.), *Energy Conservation and Public Policy* (Englewood Cliffs, N.J.: Prentice-Hall, 1979), pp. 38, 39.

[31] D.W. Jorgenson and B.M. Fraumeni, "Relative Prices and Technical Change," prepared for AEA Annual Meeting in Denver, Colo., Sept. 5, 1980.

[32] Mesarovic and Pestel, op. cit., p. 136.

cise value of these assumptions or how sensitive the results are to them.

Global 2000's short-term projections assume energy conservation in response to price ($23/barrel in 1978 dollars by 1990), above and beyond the official conservation targets of various national governments. The midterm projections extrapolate from engineering and economic forecasts for 1995 and result in a final level of conservation—48 percent reduction in the energy-to-GNP ratio by 2020—that indicates the technological limits of what can be achieved. More recent DOE forecasts of conservation are based on higher prices ($50/barrel in 1979 dollars by 1995) and on detailed analyses of specific technological possibilities in every end-use sector, many of them derived from engineering studies conducted by the Oak Ridge National Laboratory. These and other studies, combined with the demand response to the 1979 oil price hikes, suggest that long-term conservation in the 50-percent range is in fact a reasonable expectation.

Third World Energy Choices

None of the models except Global 2000 deal with the firewood crisis, which may have severe social and environmental repercussions in many Third World countries. Industrialization and economic development in these countries will also require electricity, however, and all of the models assume, at least implicitly, that nuclear power will be widely deployed in the future. This common assumption is of political as well as economic interest, particularly in the case of LAWM and UNIOWM. Both of these models represent Third World attempts to chart a future in which the gap between the rich and poor nations is narrowed through local and international efforts to accelerate development and increase industrial output. Nuclear power offers developing nations an alternative to their current dependence on fossil fuels, whether to preserve their domestic resources or to reduce their energy-related trade deficits. There is evidence that, whether or not the United States and other OECD nations finally accept the hazards of nuclear power, many Third World nations are likely to accept them on a very large scale, and very soon, for lack of a credible large-scale alternative.

Business commentators already speak of "the nuclear power boom getting under way in the Third World," including such nations as Mexico, Egypt, Korea, Taiwan, and the People's Republic of China.[33] Conventional enriched-uranium reactors in such countries represent a potentially lucrative market for the U.S. and European nuclear industries. Many Third World governments are also investigating natural-uranium technologies that would allow them to exploit domestic uranium rather than depending on Europe or the United States for expensive enriched fuel. Argentina, Pakistan, India, and South Korea already have operational reactors based on a Canadian natural-uranium, heavy-water system. Mexico's recently published National Energy Program calls for the construction of as many as 16 such reactors to meet a tripling of demand for electricity by 2000, despite that nation's abundant oil and gas reserves.[34]

The WIM "fast-nuclear" scenario, however, foresees an energy future based not on conventional fission but rather on the more efficient "breeder" reactor, which effectively produces more nuclear fuel than it consumes. As a result, breeder reactors might produce 60 to 100 times as much energy from a pound of uranium as do conventional reactors. Both past U.S. Government studies and current expert opinion suggest that, given the limited size of world uranium reserves (even including speculative reserves), nuclear fission may not be able to provide a large-scale, long-term contribution to the world's energy supply without the widespread use of breeder reactors.[35] Because breeders would also produce large quantities of weapons-grade plutonium, however, their deployment throughout the Third World could also pose a serious threat to domestic and international security.

Development Bottlenecks

Some economists would argue that the world's major energy problem is not finding adequate resources, but rather overcoming the bottlenecks in getting those resources to market. Three of the models considered here —World 3, LAWM, and UNIOWM—implicitly assume that there will be no major bottlenecks in the exploitation of energy resources. Although WIM's authors point out the numbers and speed with which reactors would have to be built for the "fast-nuclear" scenario, they do not report any further analysis of development bottlenecks. DOE's models for Global 2000 involve a serious attempt to address problems of timing where they involve liquid fuels and the transition from oil to coal and nuclear power. However, DOE's own evaluation of the 1978 long-term forecasts points out that the models describe the *requirements* for U.S. energy independence rather than the *capabilities* of the relevent industries, as well as making questionable assumptions about investor foresight, extraction costs, and environment constraints (see above). Further consideration of these and other factors suggest both that considerable cooperation between Government and industry may be needed to reduce the impact of these potential bot-

[33] H. Rowen, "Nuclear Reactors: Fear of Losing Export Race," *Washington Post*, May 17, 1981, p. K1.

[34] C. Dickey, "Scenic Mexican Reactor Site Entangles Indians, Unions, Nationalists," *Washington Post*, May 18, 1981, p. A12.

[35] See, for example, USAEC, op. cit.

tlenecks, and that other energy sources and mixes should be examined more carefully.

Future Energy Breakthroughs

Finally, the accuracy and reliability of energy projections will also be affected by the assumptions they make about the successful development and deployment of entirely new energy sources. Some such systems are implicitly assumed by one or more of the models, but others are not foreseen by any of them.

The widespread deployment of fusion technology, for instance, could possibly invalidate the pessimistic assumptions of *Limits to Growth* if the supply of lithium were large enough or if deuterium-deuterium fusion were developed. The LAWM study bases its exclusion of resource problems in part on the expectation that fusion power will in fact be deployed within 20 to 50 years. Commercial-scale fusion power remains purely speculative at present, however. Although fusion researchers hope that a commercial fusion reactor design might be possible by 1990, until then all claims about engineering problems, capital costs, and net energy production will also remain speculative. In addition, none of the models discusses the potential world reserves of lithium. Other sources, however, have estimated that minable U.S. lithium reserves alone are worth over 160,000 quadrillion Btu prior to conversion losses, or about 640 years total world energy supply at 1976 consumption levels.[36]

The WIM solar scenario envisions a long-term energy future based on centralized solar power in the form of huge "solar farms" in the deserts of the Middle East, to be financed by OPEC oil money.[37] With higher energy prices due to scarcity, the capital costs of such facilities—which the authors estimate at $20 trillion to $50 trillion in 1974 dollars—might become bearable; solar might even prove cheaper than nuclear. Theoretically it would be possible to supply all of the present U.S. demand for electricity from a "farm" of solar cells the size of Massachusetts, but DOE studies claim that there are not enough economically feasible sites in the United States for centralized solar to make more than a marginal contribution to U.S. energy supply in the foreseeable future.[38] On the vast scale foreseen by *Mankind at the Turning Point*—1 percent of the world's land surface—such facilities would involve scientific, engineering, and planning problems that are beyond the current state of the art. Furthermore, some critics question whether the energy produced by these solar farms would be greater than the total amount of energy involved in building them, maintaining them, and distributing the hydrogen and electricity they would produce. Since this scenario was not subjected to rigorous testing with the model, it remains speculative.

A number of other groups have suggested another alternative: solar-power satellites orbiting in space and beaming power down to earth in the form of microwaves or lasers. The National Aeronautics and Space Administration (NASA) has produced detailed designs for such a system, for which it envisions commercial operation by 2000, or about 20 years before fusion is predicted to become commercial. NASA studies have indicated that marginal costs and net energy production will be comparable to present energy sources, although these findings are highly controversial. DOE claims that potential receiving sites are probably more than adequate to supply several times the present level of U.S. electricity demand, since more energy can be received per acre than with central solar and without necessarily prohibiting agricultural uses of the sites, although the effects of low-level microwave radiation are problematic. Research and development costs for the NASA design, however, would be over $100 billion, and the cost per power station would be somewhat higher than that of conventional fission reactors regardless of the scale of production. An alternative design developed at Princeton University involves less R&D and employs small modular processing units whose cost and performance could be tested prior to any commitment to large-scale deployment. The Princeton design is somewhat riskier than NASA's, but it might be possible to deploy it sooner and to reduce energy costs substantially as the scale increases. This might in turn make it possible to sell energy to the LDCs at prices much lower than would be possible with breeder reactors.[39]

[36]S. S. Penner (ed.), *Nuclear Energy and Energy Politics* (Reading, Mass.: Addison-Wesley, 1976), p. 562.

[37]Mesarovic and Pestel, op. cit., pp. 139-141.

[38]*Domestic Policy Review of Solar Energy* (Washington, D.C.: Department of Energy, February 1979), table 8; DOE's long-term forecasts therefore assume an a priori limit of less than 1.0 Quad central solar by 2020.

[39]Further discussion and analysis of this technology can be found in the following sources: *Satellite Power System Concept Development and Evaluation Program Reference System Report*, DOE/ER-0023 (Washington, D.C.: U.S. Department of Energy and National Aeronautics and Space Administration, October 1978); *The Solar Power Satellite Concept: The Past Decade and the Next Decade*, NASA/JCS-14898 (Washington, D.C.: National Aeronautics and Space Administration, July 1979); R.A. Herendeen, T. Kary, and J. Rebitzer, "Energy Analysis of the Solar Power Satellite," *Science*, vol. 205 No. 4405, Aug. 3, 1979, pp. 451-454; Massachusetts Institute of Technology, Department of Aeronautics and Astronautics, Space Systems Laboratory, *Extraterrestial Processing and Manufacturing of Large Space Systems*, NASA contract CR-161293 (Washington, D.C.: National Aeronautics and Space Administration, September 1979), vol. 3, pp. 47-49; Office of Energy Research, Solar Power Satellite Project Division, *Program Assessment Report*, DOE/ER-0085 (Washington, D.C.: U.S. Department of Energy, November 1980); and Office of Technology Assessment, U.S. Congress, *Solar Power Satellites*, OTA-E-144, (Washington, D.C.: U.S. Government Printing Office, August 1981).

Office of Technology Assessment

The Office of Technology Assessment (OTA) was created in 1972 as an advisory arm of Congress. OTA's basic function is to help legislative policymakers anticipate and plan for the consequences of technological changes and to examine the many ways, expected and unexpected, in which technology affects people's lives. The assessment of technology calls for exploration of the physical, biological, economic, social, and political impacts which can result from applications of scientific knowledge. OTA provides Congress with independent and timely information about the potential effects— both beneficial and harmful—of technological applications.

Requests for studies are made by chairmen of standing committees of the House of Representatives or Senate; by the Technology Assessment Board, the governing body of OTA; or by the Director of OTA in consultation with the Board.

The Technology Assessment Board is composed of six members of the House, six members of the Senate, and the OTA Director, who is a nonvoting member.

OTA currently has studies underway in nine general areas: energy, international security and commerce, materials, food and renewable resources, health, human resources, communication and information technologies, oceans and environment, and space technology.

Senator MATHIAS. Thank you very much.

One of the problems with all of this is that I think a great many people throughout the country feel that we are all up there in the clouds somehow. To use Governor Wallace's idiom, that this is pointy-headed thinking, that it has no reality, that it has no real relevance to everyday problems and everyday life, but one of the problems that plagues America today is what to do about social security. It is widely recognized that the problem with social security is that the demographics on which the system is based have changed, and if we had been able in 1930 to look at what the profile of the American population would be like in 1980, 50 years later, we might have made some very useful alterations in the social security funding, and we would not be faced with having to make wrenching decisions within the next year or two on the future social security.

So, would you give that as an example of the value of being able to look at population trends, population forecasts, and translate that into useful public policy decisions?

Mr. GIBBONS. Mr. Chairman, I think that is an excellent example of where an implicit and important assumption was made but not examined carefully in the process of establishing the social security program. Had we asked the question. "What if the U.S. population does not continue to grow exponentially?" then we quickly would have understood that the social security system as it was being set up could be in great trouble, because that assumption was not valid.

Senator MATHIAS. Dr. Gibbons, as an officer of the legislative branch, you know that those bells mean that there is a rollcall vote on the floor which is nearing its completion, so I have no alternative but to declare a short recess. I will return as quickly as possible, and we will resume at that time. The subcommittee will stand in recess for approximately 10 minutes.

[Whereupon, a brief recess was taken.]

Senator MATHIAS. Dr. Gibbons, we have been discussing the importance of the ability to forecast trends. The "Global 2000 Report" has been subject to some criticism. The bases on which it was formulated have been criticized. The estimates have been criticized. OTA itself has been asked by the Congress to do several studies which involve long-range forecast in a number of areas. Just to give us some idea of how to measure the reliability of a report like "Global 2000," how does OTA go about the business of preparing forecasts? How were your forecasts prepared in your recent report on World Population and Fertility Planning Technologies?

As I ask you that question, let me take this opportunity to put the summary of that report in the record, because you have referred to it, and I am sure it will be referred to later in the hearing, so without objection, that report will be made a part of the record.

[The material referred to follows:]

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WORLD POPULATION

and

FERTILITY PLANNING TECHNOLOGIES

THE NEXT 20 YEARS

Summary

CONGRESS OF THE UNITED STATES
Office of Technology Assessment
Washington D C 20510

96-841 O - 82 - 10

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The Technology Assessment Board approves the release of this report. The views expressed in this report are not necessarily those of the Board, OTA Advisory Council, or of individual members thereof.

Foreword

This summary presents the major findings of the Office of Technology Assessment on world population growth and the present and prospective fertility planning technologies that will influence this growth in the future.

Rapid growth in population in the last 20 years is a result of improvement in health and agriculture technologies. Increased options for fertility change have also resulted from advances in science and technology. Because its mission includes foresight on emerging issues related to science and technology, OTA determined in 1978 that an objective analysis was timely and appropriate in providing Congress with improved insight in this area. The topic was discussed with Members of Congress and letters endorsing the study were received from the House Committee on Foreign Affairs, the House Committee on Science and Technology, and the former Subcommittee on Child and Human Development of the Senate Labor and Human Resources Committee. Permission to undertake the study was granted by OTA's Technology Assessment Board in response to a request by the Director.

The assessment covers current projections for population growth to 2000 and the implications of this growth; identifies the determinants of fertility change; reviews current reproductive research and contraceptive R&D; discusses the factors that influence the acceptance, distribution, and use of fertility planning technologies in LDCs; and examines U.S. funding arrangements in support of population assistance requests from LDCs.

Issues and options for Congress include:

- Federal support of contraceptive R&D;
- product liability and the contraceptive industry;
- effective patent life;
- export of non-FDA approved drugs;
- levels of funding for international population assistance; and
- distribution of population assistance funds.

The Office of Technology Assessment was assisted in the preparation of this study by an advisory panel of individuals representing demographic and family planning research, the pharmaceutical industry, health policy analysis, ethics and philosophy, and organizations holding differing views on current reproductive issues. Sixty-six reviewers drawn from universities, nongovernmental agencies, and the private sector provided helpful comments on draft reports. The Office expresses sincere appreciation to each of these individuals.

JOHN H. GIBBONS
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World Population and Fertility Planning Technologies

Introduction

This assessment considers the probable impacts of specific fertility planning technologies on population growth. The influence of direct factors such as age at marriage and contraceptive use on population growth is relatively well understood. Less well understood are the indirect influences—the economic, sociocultural, religious, and political forces—that modify attitudes toward family size. Detailed examination of these indirect factors is beyond the scope of this study. Nevertheless, recognition of their importance in determining the use of fertility planning technologies underlies everything that follows.

Following World War II, the world experienced a sudden sustained drop in death rates which, combined with little change in birth rates, produced unprecedented growth in the world's population. Today, about 80 million people, the equivalent of an additional Mexico or Nigeria, are added to the planet every year.

More than 90 percent of this growth is in the developing world. In the United States and other more developed countries (MDCs), infant mortality is low and life expectancy exceeds 70 years, yet populations are stable or increasing only moderately because birth rates are low. In the less developed countries (LDCs), where infant mortality, although declining, is high, and life expectancy has not yet reached 55 years, birth rates remain high and populations are increasing, often at dramatic rates.

Rapid population growth in LDCs is a key factor in limiting the ability of these countries to raise their standards of living. Important obstacles to their socioeconomic development include limited resources, food distribution problems, high rates of debilitating disease and infant mortality, lack of proper sanitation, scarcity of investment capital, and shortages of educational facilities and work opportunities. But each of these barriers to a better quality of life in LDCs is intensified by the rapid pace of their population growth.

Because LDC governments that once dismissed rapid population growth as incidental to their well-being now actively seek help with their population problems, the United States and other MDCs provide population planning assistance as part of general developmental aid to countries who

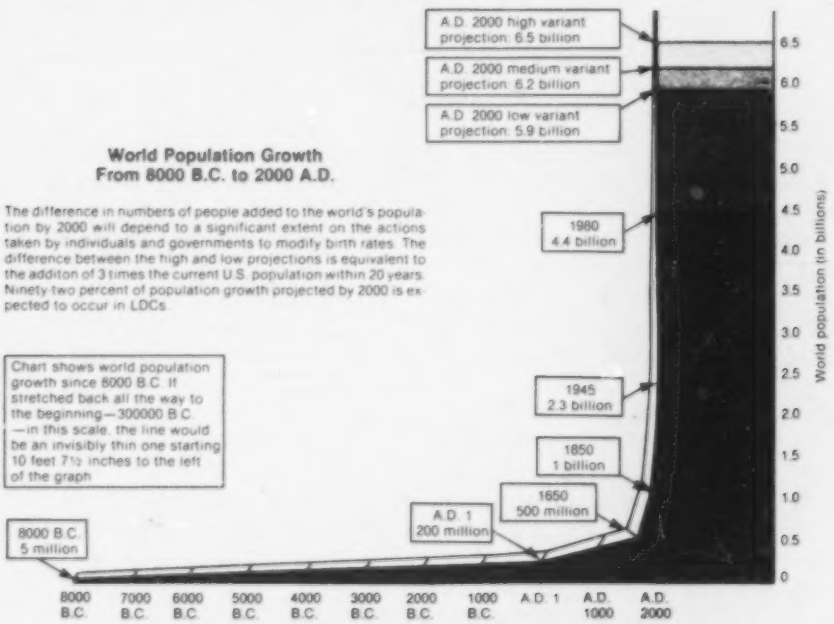
need and want help in reducing their birth rates. Such assistance has enabled many of these countries to achieve significant decreases in their population growth rates during the past decade, and there is now an international consensus that access to contraceptive services is a basic human right.

Findings and conclusions

Fertility is declining in most LDCs, but population growth is continuing at high levels because of the momentum for future growth initiated by the high birth rates and rapidly falling infant mortality rates of the recent past. More than 1 billion people will be in their peak reproductive years (ages 15 to 29) during the next two decades.

Even if growth rates continue their current decline, the world's population is expected to increase from 4.5 billion in 1981 to between 5.9 billion and 6.5 billion in the year 2000 (see fig. 1). Almost 92 percent of this growth will occur in LDCs. Growth will be greatest, according to current projections, in Africa (76 percent of the 1980 population added in 20 years), followed by Latin America (65 percent), and Asia (43 percent). But more of the increase in absolute numbers will occur in Asia (63 percent)

Figure 1.—World Population Growth From 8000 B.C. to 2000 A.D.


A.D. 2000 high variant projection: 6.5 billion
A.D. 2000 medium variant projection: 6.2 billion
A.D. 2000 low variant projection: 5.9 billion
World Population Growth From 8000 B.C. to 2000 A.D.
The difference in numbers of people added to the world's population by 2000 will depend to a significant extent on the actions taken by individuals and governments to modify birth rates. The difference between the high and low projections is equivalent to the addition of 3 times the current U.S. population within 20 years. Ninety-two percent of population growth projected by 2000 is expected to occur in LDCs.
1980 4.4 billion
Chart shows world population growth since 8000 B.C. If stretched back all the way to the beginning—300000 B.C. —in this scale, the line would be an invisibly thin one starting 10 feet 7½ inches to the left of the graph
1945 2.3 billion
1850 1 billion
1650 500 million
A.D. 1 200 million
8000 B.C. 5 million
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
World population (in billions)
8000 B.C.
7000 B.C.
6000 B.C.
5000 B.C.
4000 B.C.
3000 B.C.
2000 B.C.
1000 B.C.
A.D. 1
A.D. 1000
A.D. 2000

SOURCE: United Nations, *World Population Trends and Prospects by Country, 1950-2000: Summary Report of the 1978 Assessment*, New York, 1979, projections 1980-2000; Arthur H. Westing, "A Note on How Many Humans Have Ever Lived," *Bioscience*, vol. 31, 1981, pp. 523-524. Graph adapted from "Population Growth from 8000 B.C. to the present," Oct. 6, 1981, © 1981 by The New York Times Company. Reprinted by permission.

than in Africa (22 percent) or in Latin America (15 percent), simply because many more people already live in Asia. Three-quarters of all LDC growth is expected to occur in just 18 countries: India, China, Brazil, Nigeria, Indonesia, Bangladesh, Pakistan, Mexico, Philippines, Thailand, Vietnam, Turkey, Iran, Egypt, Ethiopia, Burma, South Korea, and Zaire, listed here in the approximate order of the magnitude of their projected growth.

The striking momentum of world population growth means that the number of births expected each year will increase despite falling fertility rates, because the number of people in the reproductive ages (15 to 44) is increasing.

Even when countries achieve replacement-level birth rates, stationary population growth—the stabilization of deaths and births at near equal levels—cannot be achieved until members of the largest age group (those between 0 and 4 years) reach old age some 60 years later.

Current declines in fertility are unevenly distributed among LDCs but many of those with the largest populations have achieved the greatest declines. China's birth rate has declined dramatically. Estimates of fertility decline between 1965 and 1981 range from 17 to 58 percent. South Korea's fertility has fallen by 34 percent, Colombia's by 34 percent, and Thailand's by 36 percent during the same period.

Significant fertility declines are usually associated with some or all of the following conditions that involve government policy and action with regard to population programs (ordering does not imply relative importance): 1) governmental policies that encourage and promote equal status and opportunities for women, higher age at marriage, and more equitable distribution of wealth and educational opportunities, all of which lead to a higher standard of living; 2) programs designed to bring about a decline in infant mortality; 3) a government policy with explicit goals for reduction of birth or population growth rates; 4) a strong commitment to population planning by the country's leaders; 5) a family planning organizational structure with executive power to mobilize more than one government sector and to coordinate with the private sector; 6) population program funding (usually both external and internal sources); 7) provision of a broad range of contraceptive methods; 8) sufficiently trained and motivated family planning program personnel; 9) population and family planning information, education, and communication (IEC) efforts that effectively reach all sectors of the population; and 10) direct or indirect incentives that encourage couples to limit the size of their families. The relative importance of these components is not known because country settings differ, and the nature of the country's developmental process and the level of certain key indicators (life expectancy, gross national product (GNP), nonagricultural labor force participation, literacy rates, etc.) affect the extent to which a program can succeed in lowering fertility. But the degree of political will and commitment and the extent of administrative capacity play major roles in determining the magnitude of fertility decline.

Most people in the developing world live in countries that now consider their rates of population growth higher than desirable and want help in achieving lower rates. Recent experience has shown that growth rates can be slowed, often with startling success, despite the momentum inherent in LDC age structures. Although other development factors influence fertility, both stronger family planning programs and more effective, safer, and easier-to-use contraceptive methods can make important contributions to slowing population growth in the next two decades.

If governments decide to take actions to reduce population growth in addition to those actions currently planned, the world's population in 2000 will be closer to the lower estimate of 5.9 billion than to the upper estimate of 6.5 billion. Even the low projection, however, means that today's 4.5 billion world population will increase by 1.5 billion in just 20 years. For the longer term, additional efforts undertaken now can be still more decisive because of the difference between the high and low projections for 2050: a world population of 8.4 billion instead of one of 12.4 billion, a difference nearly equal to today's global total.

Countries that wish to reduce their population growth rates have three options: raise mortality rates, encourage emigration (or discourage immigration), or reduce fertility rates. The first is morally untenable, and the second is not feasible over the long term because there are no countries left to accept vast numbers of immigrants. The only viable solution is to lower fertility rates. Many LDC governments have already decided to encourage this latter option; in the last 20 years, the proportion of the world's people who live in countries that provide support for family planning services has risen from about 10 percent to 90 percent.

Most LDCs face similar environmental and economic problems. In a number of these countries, the need to increase food and fuel production has led to significant environmental degradation through denuding of forests, transformation of productive land into desert, and waterlogging and salinization of irrigated land. The large balance-of-payments deficits and increased debts confronting most oil-importing LDCs in recent years have depressed their rates of economic growth, lowering prospects for meeting basic health care needs, and making the provision of jobs a formidable task.

The collective effects of these continuing environmental and social problems, exacerbated by rapid population growth, have led to increased international migration and political instability. U.S. interests are directly involved, for example, in present immigration pressures from Mexico, the Caribbean, South America, and Southeast Asia.

Rapid population growth is an intensifier of current environmental, food, energy, and resource pressures in LDCs, and its interaction with these problems is generating a new category of national security concerns. The implications of this interaction for national security, a term that is itself changing, remain largely unexplored.

Direct fertility determinants

Aside from indirect influences such as levels of socioeconomic development, education, and family size preferences, four factors have a direct and important impact on the number of births that will occur in the next 20 years: age at marriage, prevalence of breastfeeding, prevalence of induced abortion, and—the most significant—use of contraception.

Young age at marriage and near universality of marriage in the absence of widespread contraceptive use are important causes of high birth rates in many countries. High infant, child, and adult mortality in association with the social stigma attached to illegitimate births has necessitated very young age at marriage and maximum reproduction to ensure survival of the family lineage. Increases in age at marriage have contributed to fertility decline in many LDCs in recent years and may continue to do so in such areas as the Asian subcontinent, where age at marriage remains low.

Breastfeeding delays the return of ovulation after childbirth, sometimes for as long as a year or more. If large numbers of women breastfeed for long periods, a natural form of birth-spacing occurs that can cause a modest reduction in overall fertility rates. But breastfeeding is an important influence on fertility only in societies with high fertility rates. Breastfeeding is an imperfect individual contraceptive because the amount of protection against pregnancy that it confers is extremely variable. In LDCs, fewer women are now choosing to breastfeed, and many women are breastfeeding for shorter lengths of time.

The limitations of current contraceptive technologies and lack of access to their use cause many women in all parts of the world to seek induced abortion to terminate unwanted pregnancies. Induced abortion is a medically safe procedure when performed early in pregnancy by skilled personnel. But the risk of maternal death or serious complications increases greatly when it is performed by less skilled personnel in marginal facilities and when it is performed later in pregnancy. Rates of induced abortion are high in LDCs, even though its legal use is constrained in some countries by religious beliefs. It is rarely a preferred method of fertility planning, but is resorted to when other means are not available, or fail.

Of all the means available, contraceptive use is by far the most important in lowering fertility. On average, women are fecund (capable of bearing children) from age 15 to 45, about 30 years. In the absence of contraception and allowing for time spent pregnant and infertile (due to infertility following birth or to breastfeeding), and time not spent in union because of divorce or widowhood, a woman could expect to have an average of about 10 children. If reduction of fertility rates to those associated with population stabilization (about 2.2 births to each woman) is desired, it is necessary that some method of contraception be used for up to 25 years.

The major methods of contraception currently in use are:

- Sterilization—vasectomy in the male, and tubal ligation/occlusion in the female.

- Steroid hormones—combined (estrogen and progestin) or low dose progestin oral pills, or intramuscular, long-acting progestin injections. These synthetic steroids are given in different combinations and different doses, depending on the commercial product, but they act primarily by inhibiting ovulation through suppression of the hypothalamic hormones that stimulate the release of follicle stimulating hormone (FSH) and luteinizing hormone (LH) from the anterior pituitary. The synthetic steroids also cause endometrial changes that make the uterus inappropriate for implantation should breakthrough ovulation and fertilization occur. Other changes that contribute to the contraceptive effect include scant and thick cervical mucus, reduced sperm transport and penetration into the uterus, and altered sperm and ovum transport within the fallopian tubes.
- Intrauterine devices (IUDs)—the insertion of a foreign body, made either of an inert substance or impregnated with other materials (copper, progesterone). Although the IUD prevents implantation in some mammals, its mode of action is unknown in the human being. There are several possible modes of action, from interference with sperm transport, to interference with ovum transport, to interference with implantation in the uterus. There is also some evidence that IUDs lead to increased sperm damage and affect the motility of the ovum in the fallopian tube.
- Barrier devices—the condom for the male and the diaphragm and cervical cap for the female.
- Vaginal spermicides—high viscosity fluids that both kill sperm and block them from entering the cervical canal.
- Coitus interruptus—male withdrawal prior to ejaculation.
- Periodic abstinence (rhythm, natural family planning)—timed to avoid coitus near the day of ovulation.
- Postcoital douches—water or spermicidal solutions that flush out and kill sperm in the vagina.

Between now and the end of the century, more than 20 new or significantly improved technologies for contraception are expected to become available. Highly likely to be available by 1990 are:

- Steroid hormones: safer oral contraceptives, improved long-acting steroid injections, and two new methods of administration—steroid implants (e.g., capsules in the forearm) and steroid vaginal rings.
- IUDs: three improved types are anticipated. Improved versions of the copper-releasing IUD will be effective longer than current IUDs. Advanced versions of the progestin-releasing IUD may be as effective as the pill and require replacement only every 5 to 10 years. Postpartum IUDs, which can be safely inserted immediately following delivery without excessively high expulsion rates, will make IUDs available to large numbers of women in LDCs who otherwise might lack access to the medical personnel needed for insertion of other types of IUDs.
- Barrier devices for women: one-size-fits-all diaphragms, disposable diaphragms, spermicide-impregnated diaphragms, vaginal films, vagi-

nal sponges, vaginal rings that release spermicides, and cervical caps that can be left in place for weeks or months.

- Improved ovulation-detection procedures for use with periodic abstinence methods: a wide variety of biological and biochemical parameters are altered when a woman ovulates, and researchers are endeavoring to improve or simplify the physical tests that a woman can use herself to determine when she ovulates. Improved methods of evaluating changes in cervical mucus, hormones in urine or saliva, and basal body temperature would enable greater numbers of users of periodic abstinence to know with certainty when they could safely engage in sexual intercourse during the second half of the menstrual cycle without risk of pregnancy, although the prediction of ovulation is likely to remain problematic.*
- New hormonal methods: methods that would reversibly inhibit ovulation using synthesized agonists or antagonists to one of the hormones that controls ovulation, luteinizing-releasing factor (LRF).
- Drugs that induce menstruation: prostaglandin analogs that depend on uterine muscle contraction for their action. Administered as vaginal suppositories, these drugs can also induce abortion during the first 8 weeks of pregnancy in about 90 percent of cases.

Beyond 1990, fertility planning technologies may include a monthly pill or injection, antifertility vaccines for men and antipregnancy vaccines for women, ovulation prediction methods, simplified and reversible sterilization procedures, LRF analogs for self-administered induction of menses, and lactation-linked orals for women.

Most R&D on contraceptives has been conducted by MDC governments and the pharmaceutical industry. Prior to 1967, contraceptive R&D was financed largely through the private sector. In the 1970's, however, of funds spent worldwide on reproductive research and contraceptive development, private industry provided about 10 percent, and governments and philanthropic and nonprofit organizations provided 90 percent.

The market approval process of the FDA affects population planning assistance, because the U.S. Food, Drug, and Cosmetic Act prohibits pharmaceutical manufacturers from exporting drugs for uses not approved for marketing in the United States. This policy is based primarily on the premise that one standard of drug approval is necessary, and under this premise, the United States would be promoting a double standard if it exported drugs not approved for use in the United States.

The FDA approval process for all drugs averages 7.5 years. FDA requirements for the specific types of tests and test animals to be used in providing safety and efficacy data for contraceptives usually make the average length of the approval process for contraceptive drugs longer than for other drugs by about a year. This is because contraceptives are given to young, healthy individuals and can potentially be administered

*Such methods would also benefit couples with infertility problems by pinpointing the fertile period.

over a period of 30 years, whereas other drugs are usually used to treat diseases and/or are often administered only for a few weeks at most.

Drug patents run for 17 years, but effective patent life is shortened by the regulatory process. For oral contraceptives, however, shortened patent life has not affected the original manufacturers' abilities to retain a large share of the market even when prices were increased after the patent period had expired.

But expanding product liability has escalated costs and made the prediction of future costs uncertain for both the pharmaceutical industry and its insurers. As in the case of patent life, these difficulties are being experienced by all drugs (and products in general), but the contraceptive market has been especially affected by product liability problems.

Rising product liability costs and the ability of manufacturers to retain their market share even after patents expire signify higher prices for contraceptives and reduced purchasing power for family planning programs.

International population assistance

International population assistance evolved in response to growing awareness of the problems that accompany rapid population growth and to requests from LDC governments for technical assistance in addressing these problems. The purposes for which population assistance funds are expended include: 1) development of population planning policies appropriate to the recipient country; 2) contraceptive commodities; 3) systems for contraceptive distribution and use; 4) IEC activities; 5) research on the delivery of family planning services, on the development and application of improved or new contraceptive methods, on the social, economic, and cultural conditions that affect their acceptance and use, and on those social conditions that directly affect birth rates (e.g., age at marriage); and 6) the gathering, evaluation, analysis, and dissemination of demographic and other information.

Less than 2 percent of official development assistance from all MDC donors is currently allocated to population activities, a proportion that represents a small decline since 1970. The United States provides just under 4 percent of its total development assistance for international population activities.

In 1980, total resources (excluding China) committed to population and family planning programs in LDCs amounted to about $1.0 billion. Of this total, LDC contributions accounted for about $450 million, private sources about $100 million, and MDC sources about $450 million. Donor governments (including the United States) are the principal source of MDC assistance; funds are channeled: 1) through nongovernmental organizations (NGOs) such as the International Planned Parenthood Federation (IPPF) and Family Planning International Assistance (FPIA); 2) directly to LDC governments (bilateral assistance); and 3) through multilateral organizations such as the United Nations Fund for Population Activities

(UNFPA). Private sector donors channel money primarily through NGOs such as IPPF. MDC and private contributions arrive in LDCs as money, contraceptives, information, and technical assistance in developing and administering family planning programs and in collecting and analyzing population data. Agencies administering the largest amounts of population assistance are the U.S. Agency for International Development (AID), UNFPA, and IPPF.

The United States supports population assistance through two main channels, AID (Office of Population) and the World Bank. The World Bank receives moneys in the form of general development appropriations, about 1 percent of which are directed toward population projects. AID, in turn, channels funds bilaterally to LDC governments, multilaterally to UNFPA, and through private intermediary organizations, such as IPPF, FPIA, etc. World Bank support is exclusively loan assistance; AID programs are largely grant assistance but include some loans as well.

In fiscal year 1979, AID bilateral assistance totaling $48 million went to 33 LDC governments. NGOs channeled an additional $90 million from AID into technical assistance to 64 LDCs. Multilateral assistance totaling $30 million from AID went to UNFPA (26 percent of UNFPA's budget), which UNFPA in turn granted to 116 LDCs. IPPF channeled $22 million of AID funds (28 percent of its budget) to private IPPF affiliates in 88 LDCs.*

The amount of U.S. population assistance channeled through AID rose from $5 million in 1965 to $185 million in fiscal year 1979. This figure remained constant in 1980 and increased to $190 million in 1981 through continuing resolutions. The 1982 appropriation has been increased to $211 million; the authorization for fiscal year 1983 is $230 million.

Although the United States continues to provide the most population assistance to LDCs, its proportion of the total amount has decreased over the last 14 years. The United States provided 50 percent or more of all primary source assistance until 1974, when this proportion leveled off to about 40 percent, where it has remained. This decrease is largely due to increased contributions from other MDC donors, including the Scandinavian countries, Japan, and West Germany. In addition, the impact of inflation cut the 1981 funding level, in constant dollars, to $41 million below that of the peak year of 1972 ($121 million). The 1982 appropriation is $28 million below the amount required to maintain the 1972 level.

International population programs

Family planning programs contribute significantly to improved health of women and children and have made a substantial difference in accelerating the rate at which fertility declines. In countries with strong family planning efforts for which data are available, fertility declined an average of 30 percent between 1965 and 1975. This compares with declines of

*The usual funding level is about $12 million; this $22 million included forward funding to alleviate IPPF cash flow problems and the fiscal year 1980 appropriation was reduced accordingly.

about 4 percent in similar countries with weak family planning programs and 2 percent in countries with no programs. On balance, about 15 to 20 percent of the declines in fertility between 1965 and 1975 in 94 LDCs is attributable to the family planning component of population program effort.

The need for greater sensitivity to and knowledge of the role of the sociocultural factors that motivate people to adopt family planning is clear. Multifaceted programs that address relevant social, economic, and health needs along with delivery of family planning services are most likely to be successful.

The use of fertility planning technologies can substantially lower birth rates, but their availability and acceptability vary. Delivery systems may be inadequate or culturally inappropriate so that family planning services are in fact not effectively available. The contraceptive methods used in a particular country may not be the ones preferred but the ones available. People may become dissatisfied and discontinue the methods used because of side effects, the need for repeated application, costs, medical contraindications, contraceptive failure, and concerns about long-term safety. A realistic goal is for each country to have enough technologies appropriate for local conditions so that each individual has access to at least one method that meets his or her current needs. Improved and new technologies could enhance family planning effectiveness and efficiency by reducing side effects, permitting easier administration, and simplifying delivery system requirements.

At present, of 374 million couples of reproductive age in LDCs (excluding China), some one-fifth, or about 74 million, are using contraception. By 2000, there will be at least 638 million couples of reproductive age (889 million couples if China is included). Because about 80 percent of these couples would need to use some form of contraception if fertility were to approach replacement levels, the number of couples practicing family planning regularly and consistently would have to increase about sevenfold in the next 20 to 30 years.

Program costs per user currently range from $6 to $100 annually in LDCs, for an average of about $15 per user for an efficient family planning program (one that combines public and private sectors, provides access to voluntary sterilization, includes IEC activities, demographic data collection and analysis, and adequate infrastructure support). In order to increase current contraceptive use to the 80 percent of all couples of reproductive age necessary to approach replacement fertility levels, 300 million LDC couples (excluding China) would now have to be practicing contraception. Although contraceptive use is not expected to exceed 50 percent by 2000, if it were to reach the 80-percent level it would require, using the $15 cost per user per year, a minimum total international population support budget of $4.5 billion annually, including the contributions of LDCs. (This figure excludes China, where expenditure data are fragmentary.) Using the same assumptions of cost per user, and using 1980 dollars, the rise in numbers of couples in the reproductive ages

would increase this cost to about $7.4 billion in the year 2000. (Under this formula, the amount rises to $10.7 billion when China's childbearing-age population is added.)

Program emphasis will shift in coming years as LDC needs change. There will be greater emphasis on reaching rural populations, heavier reliance on private sector delivery systems, increased integration with other components of development, and decentralized approaches to meeting community-level needs. Management training will be crucial as the demand for services grows, as will increasing work opportunities for women in all sectors of development, including family planning programs.

Because LDCs consider the slowing of their population growth an urgent need and the lead time required to make new contraceptive methods available is relatively long, the methods that should be emphasized in the next decade are those already in hand and those that will become available in the next few years. Experience with family planning programs in LDCs indicates that if commitment is strong, if delivery systems are adequate and culturally acceptable, and if a broad range of methods is made available, the pace of fertility reduction can be enhanced. Although imperfect, currently available contraceptive methods can provide the basis for fertility reduction, but further biomedical research is critical to improving the safety, efficacy, and acceptance of contraceptives.

For policymakers concerned with modifying population growth, the most meaningful population information is the difference in numbers of people added to the world's population if governments do or do not take feasible actions to reduce birth rates in addition to those already under way. The actual amount attributable to additional governmental actions that reduce birth rates is neither accurately known nor explicitly stated by most demographic experts who make projections. There is general agreement, however, that if governments intensify current actions to reduce growth rates, the low variant projection is more likely to be achieved. The total difference between the high and low variants is sizable—650 million persons—and is equivalent to the addition of three times the current United States population in just 20 years.

Issues and options

The breadth of purpose of international population assistance, the range of its activities, and the variety of U.S. governmental involvement in these activities result in many issues of congressional interest. Not all of these issues require legislative action, and many can be examined through the congressional oversight process. In this section, the principal issues and related legislative options for: 1) Federal involvement in contraceptive R&D, and 2) international population assistance support are addressed.

In the biomedical research area, the issues center on the U.S. Government's key role in support of reproductive and contraceptive R&D and on reconciling how the United States regulates the drugs and medical devices

industries with the need to diffuse these technologies to countries that may have different risks or perceptions of risks.

Contraceptive technologies

The U.S. Government's role in the development and dissemination of contraceptive technologies is mediated through two avenues: 1) the R&D activities of the National Institutes of Health and AID; and 2) the regulatory policies of FDA. Peripheral to contraceptive technologies, but possibly affecting them, are U.S. patent laws and their interrelationships with FDA's regulatory process and the direction that product liability legal doctrines have taken in the United States.

THE ROLE OF THE U.S. GOVERNMENT IN CONTRACEPTIVE R&D

The Federal Government not only supports contraceptive R&D, but also regulates the drug and medical devices industries through FDA's market approval process in which efficacy and safety requirements must be met. The development and dissemination of contraceptive technologies thus can be influenced through Federal funding of contraceptive R&D, and through governmental actions that could stimulate or restrain expanded or renewed interest in contraceptive products by private industry.

ISSUE: Federal support of contraceptive R&D

In 1979, governmental agencies throughout the world provided approximately 80 percent of funding for reproductive research and contraceptive development. The United States provided nearly 60 percent of all funds, or about $89 million. Approximately 70 percent of worldwide expenditures were devoted to basic research, training, and institutional support; about 23 percent to contraceptive development; and approximately 7 percent to evaluation of current methods.

OPTIONS:

A. Sustain financial support of R&D at current levels.

If Congress continues to judge that governmental action is warranted to continue the development of improved contraceptives for use at home and abroad, the minimum action would be to sustain support of existing programs at current levels. Although the dollar amount for reproductive research and contraceptive development increased from $80 million in 1972 to $112 million in 1979, inflation has meant, in terms of constant dollars, a cut of about 20 percent from the 1972 funding level.

B. Substantially increase financial support.

Arguments for increases in contraceptive research include the following: Present contraceptive development programs may develop many useful new and improved contraceptives over the course of the next two decades if additional money is available. Because many LDCs are actively pursuing policies to reduce population growth and there is increasing concern in MDCs about the side effects of current fertility planning meth-

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ods, there is a strong need for improved contraceptive methods both in the United States and abroad. The potential impact is enormous in terms of improved family planning effectiveness, reductions in numbers of unwanted pregnancies and induced abortions, improved maternal and family health, alleviation of human suffering, and opportunities for economic progress. Without such added investments, emergence of many new contraceptive products is likely to be either prevented or very substantially delayed.

Congress could authorize and appropriate more funds for the entire field of reproductive research, using the presently available funding channels, NICHD and AID. Alternatively, Congress may wish to increase funding only for contraceptive development. Added investments in this specific area are highly likely to produce payoffs in the form of useful new technologies. As total public funding for such development is currently less than $20 million annually, present funding levels could be significantly increased at relatively low cost. An additional $20 million annually in this specific field could have a substantial impact.

The budget of AID's Office of Population also could be augmented and earmarked or recommended for contraceptive development, which would enable AID to increase funding for both the three U.S.-based international contraceptive development programs and other groups that could contribute to this endeavor.

Increases in NICHD's budget would need to be earmarked for the Contraceptive Development Branch. Such action would greatly increase the volume of goal-oriented R&D being conducted under contract by NICHD. This action would contribute directly to the development of new contraceptives for U.S. use and indirectly to the work of international programs seeking to develop and introduce new contraceptives in LDCs.

C. Reduce financial support.

Although it could be argued that industry invests little in contraceptive R&D because government funds are available, and that one impact of this option would thus be increased industry participation, such factors as product liability are major deterrents to greater industrial participation in contraceptive R&D. For basic reproductive research, the additional factors of longer time for return on investment and greater risk further deter industrial participation in fundamental research.

A reduction exclusively in NICHD's budget would rapidly result in a discontinuation of research by many U.S. research centers now working in this field under NICHD support. Much of the Nation's safety research on contraceptive methods currently in use would also be eliminated. At least initially, the direct effect on the U.S.-based contraceptive development programs to which AID contributes (IFRP, PARFR, and ICCR) would be minimal, as they are not funded by NICHD. But because these other programs utilize basic research and goal-oriented research findings that emerge from NICHD-funded projects, over the long term their prospects

for successful development of new methods could be reduced significantly.

A reduction exclusively in AID's contraceptive development program likely would be detrimental for at least three of the four nongovernmental contraceptive development and dissemination programs.

STIMULATE THE INTEREST OF PRIVATE INDUSTRY IN CONTRACEPTIVE R&D

Most of the numerous factors that might stimulate more private industry interest in contraceptive R&D concern removing apparent disincentives against developing and marketing of contraceptive products. But as these factors also involve major issues in their own right, trying to change these factors to promote contraceptive R&D quickly impinges on other substantial interests. Hence, although options for some factors are discussed here, it should be kept in mind that the effects of these changes would reach beyond contraceptives to other drugs and other products.

ISSUE 1. Product Liability and the Contraceptive Industry

According to representatives of companies actively researching new contraceptive products, product liability is as great a negative factor in making a business decision regarding new contraceptives as meeting the FDA requirements for safety and efficacy.

The primary effect on a manufacturer from product liability is financial; i.e., compensation for claimants and defense of claims. A secondary effect is the adverse publicity accruing to the product and its manufacturer. Because of increasing frequency of claims and escalating size of successful judgments against contraceptive manufacturers, pricing of liability insurance has become so uncertain that insurers are either withdrawing from the field, mandating that manufacturers self-insure larger and larger amounts of first-dollar costs, or placing contraceptive drugs and devices in special categories of risk separate from product liability insurance for the manufacturer's other products.

As liability costs are business expenses that are incorporated into the price of the affected product, manufacturers may be increasingly reluctant to devote research and development efforts to products such as IUDs. Once the sale is made, there is less opportunity to recoup liability costs, as sales are not as frequent and continuous as they would be for oral contraceptives. With the latter, liability costs can be passed on, which may explain in part the large price increases of oral contraceptives (discussed next) in comparison with other drugs. Thus, product liability may be affecting not only the propensity of private industry to develop new contraceptives but also the kinds of contraceptives to be developed in the future.

ISSUE 2. Effective Patent Life

The current process through which drugs and medical devices are cleared for commercial distribution and sales takes a number of years. However, in order to protect its interest in the potential new product, a

company must apply for and be granted a patent long before the product has been approved by FDA. Drug patents run for 17 years, but it takes an average of 8.5 years for a contraceptive drug to clear the regulatory process, cutting its effective patent life to less than 9 years. Whether this situation inhibits the development of new drugs and medical devices is not clear.

Wyeth Laboratories and Ortho Pharmaceutical share approximately 70 to 80 percent of the U.S. market for oral contraceptives. Wyeth's patent on norgestrel is still in effect, but the patent on norethindrone expired in 1973. Since the patent expiration, only Mead-Johnson and Lederle have entered the market, and Lederle no longer markets its oral contraceptive. No generics (nonbrand name drugs) have entered the market. The Pharmaceutical Manufacturers Association also reported in August 1980 that oral contraceptives had the greatest price increases of all classes of pharmaceuticals in the periods 1969 to 1979 (187 percent) and 1978 to 1979 (23.7 percent), as compared to only a 37.4 percent increase in price during 1969 to 1979 and a 6.5 percent increase in 1978 to 1979 for a sample of over 1,000 drugs. Although other factors (e.g., product liability) may be at work, shortened patent life has not had a significant effect on the oral contraceptive market. After patents have expired, prices have remained high and new firms have not been able to enter the market on a competitive basis.

ISSUE 3. Export of Non-FDA Approved Drugs

The market for U.S. manufacturers of contraceptives could be expanded if the law on the export of non-FDA approved drugs were changed.

Current law prohibits the export of drugs for uses that are prohibited in the United States. Two categories of drugs are at issue: 1) drugs unevaluated for use; and 2) drugs evaluated but not approved for use. There are some exceptions to the drug exportation ban: e.g., investigational drugs can be exported for investigational purposes, provided that the importing country's government has approved such imports. In addition, medical devices not approved for marketing in the United States can be exported if: 1) they conform to the laws and specifications of the importing country; and 2) their export is not considered by the Secretary of Health and Human Services to be contrary to the public health and safety of the importing country.

Changes in the export provision of non-FDA approved drugs have been considered by Congress. In the 96th Congress a bill adopting the medical devices export law for drugs was passed by the Senate but died in the House of Representatives.

OPTIONS

A. Keep the status quo, where drugs not approved for marketing in the United States cannot be exported to other countries but medical devices can be exported under certain conditions.

By keeping the status quo, Congress prevents the foreign marketing of drugs that have not been adequately tested or whose safety has not been established by U.S. standards.

However, the relative risks and benefits of a drug are not the same for people in LDCs, where health conditions, including the risks of pregnancy and childbearing, are quite different from those in the United States. Further, the wide range of contraceptives available to U.S. women may not be available to women in LDCs, a factor that affects the risk/benefit assessment of a particular contraceptive. Thus, the United States may be depriving women in LDCs of drugs that would have a greater benefit than risk for them.

B. Adopt the medical devices export law for drugs.

As in the case of medical devices, non-FDA approved drugs could be exported, provided that the specifications and laws of the importing country were met, and the Secretary of HHS determined that the importing country's public health and safety were not compromised.

C. Adopt the medical devices export law for drugs, and add one or more of the following provisions:

1. Require that the risk/benefit analysis for an unapproved drug take into consideration conditions of the drug's use (and other health risks) to individuals in the importing country

This provision is based on the assumption that the risks and benefits of a given drug can change from country to country. Some advocates of this provision believe that a risk/benefit analysis of a drug should be based on data actually obtained in the importing country and in response to requests from that country. Determination of a drug's benefits would be based on the prevalence and severity of the target medical condition, and safety assessments could consider such items as the extent to which the drug user could be monitored for adverse reactions. Other user conditions—e.g., nutritional status—that could affect a drug's safety and efficacy could also be studied.

Instead of actually collecting data from clinical trials conducted in the importing country, it may be more feasible to adjust data collected from other countries to reflect user conditions and disease prevalences in the importing country. It is very difficult to collect data from a sufficient number of women within any given country when low-incident, but very important, medical events are to be assessed.

2. Establish industrial standards of conduct.

Procedures could be developed in which officials—and perhaps the public—in importing countries could be informed of the risks, benefits, and costs of the drugs they wish to import. Written verification of such an informed consent process, signed jointly by company executives and importing country officials, could be filed with the Secretary of Health and Human Services (HHS). Violation of that document could serve as a basis for withdrawal of approval.

D. Develop international standard-setting mechanisms on the use, safety, and effectiveness of contraceptive drugs and devices.

If modifications of existing export laws on drugs along the lines of the current medical devices export law (options 2 and 3) are adopted, such international standards would be helpful to the Secretary of HHS in determining whether or not the importing country's public health and safety are compromised.

INTERNATIONAL POPULATION ASSISTANCE

Many LDCs now actively seek population assistance and their requests for population assistance have risen to the point that donor agencies can meet only a fraction of current requests for such aid.

ISSUE 1. Level of Funding

OPTIONS:

A. Reduce financial support.

Reduced support from the United States for population programs would force LDCs to reduce their programs, cut back on supplies that require foreign exchange, eliminate training programs, and probably decrease program outreach to rural and other hard-to-reach areas. Because the momentum for population growth already exists, spending for population programs deferred now would still be necessary at higher funding levels because of inflation, loss of trained personnel, and duplication of start-up costs. The capability of LDCs to finance their own family planning programs through such promising avenues as commercial retail sales (CRS) programs would be postponed. (CRS programs provide oral contraceptives, condoms, and spermicides at low cost and can effectively extend to hard-to-reach areas. However, they require substantial initial funding for bulk procurement of contraceptives, subsidizing of retail prices, and technical assistance in the establishment of backup medical services.) Also, if the U.S. level of support were to be decreased now, self-sufficiency of LDCs in population planning and progress in economic development might be further delayed, resulting in: 1) deteriorating social and economic conditions including increased death rates in LDCs; 2) need for significant future increases in general economic developmental assistance from MDCs to LDCs; or 3) if the United States were to abstain from future increases in economic developmental assistance, widening of the economic chasm between MDCs and LDCs, with all of the political implications that are associated with these differences.

Overall, U.S. cuts would disrupt the current working balance among private organizations, intergovernmental agencies, and government donors, with particularly adverse effect on the private agencies that are likely to suffer major reductions yet are often the most cost effective. Under current budgets, AID and the multilateral donors cannot meet current commitments. With further cuts, many countries and agencies would have to reconsider their ability to implement effective programs.

The U.S. Government, as the largest single donor to international population assistance, has been able, to some degree, to coordinate population assistance efforts and influence the direction of funding. A reduction in population assistance funds would reduce U.S. influence on program strategies and design.

B. Increase financial support.

Congress has in fact increased its appropriation from $190 million in fiscal year 1981 to $211 million in 1982; $230 million has been authorized for 1983. These current and potential increases represent a significant step and underscore the importance of population assistance at a time when many high priority social programs are being cut. However, inflation has reduced the purchasing power of these funds to below that of the total amount provided for population funding in the peak year of 1972 ($121 million, or about $239 million in 1982 dollars). At a time of rising requests for assistance, the AID population commitment is decreasing in purchasing power.

AID's fiscal 1982 budget is about $200 million below levels of documented need and insufficient to the point that: 1) most AID-supported projects and programs will receive less than the funds needed to satisfy demand for family planning services or otherwise function optimally (this includes inability to meet shortfalls at UNFPA, IPPF, and other major private voluntary organizations); 2) there will be few new initiatives in Africa (where governments are now beginning to ask for assistance) and the Near East; and 3) projects are being terminated prematurely, before recipient countries become self-sufficient.

UNFPA's 1982 calendar year budget of $135 million represents a shortfall of $40 million to $100 million. The $40 million represents the gap between available funds and established needs for ongoing programs and commitments previously made. The $100 million includes new programs that have been requested and merit funding, but for which funds are not available. However, a much larger number of countries now wish population assistance, and there has been a 20 percent increase in couples of childbearing age in LDCs since 1972.

Excluding China, only 20 percent of couples of reproductive age are currently using contraception in LDCs. Efficient programs cost an average of $15 per user annually (new programs can cost as much as $100 per user). Many countries are only beginning to implement family planning programs so start-up costs are very high. If fertility is to fall to replacement levels, contraceptives must be used by about 80 percent of couples in the childbearing ages. The growth in the population, the need for increased use of fertility planning methods, and higher costs of programs that cannot be fully implemented until LDCs themselves can contribute more support all argue for major incremental increases in population assistance in the coming years.

One approach to steady incremental increases in funding would be to meet the recommendation of the International Conference of Parliamentarians on Population and Development held in Colombo, Sri Lanka in 1979. Delegates representing 58 countries unanimously called for a total annual allocation of $1 billion in international population assistance (exclusive of LDC commitments) by 1984.

More recently, at the International Conference on Family Planning in the 1980's held in April 1981 in Jakarta, Indonesia, participants from 76 African, Asian (including China), Latin American, and Middle Eastern countries joined representatives of major international agencies in calling for a rapid increase in overall national and international expenditures for population and family planning programs to $3 billion annually.

Assuming that the United States wishes to maintain its 40 percent share of the total assistance budget and that other MDCs and private sources increase their contributions, the goals set by these international representatives might be attained, although the timing is likely to be delayed. If the United States were to increase its contributions by 30 percent per year (assuming an annual inflation rate of 15 percent), its contributions could keep pace with inflation and incremental funding would be available for increasing needs. The United States would thereby maintain its leadership position in population assistance and would contribute significantly to meeting requests from LDCs for assistance with a problem most of these countries now view as high priority.

ISSUE 2. Distribution of Population Assistance Funds

Present channels and content of population assistance programs reflect both the priorities of the assistance agencies and the needs of LDCs. A change in the present distribution system would affect the type of aid available and hence would have different impacts on different regions.

Because of differences among regions, wide-ranging approaches are required. In general, Asia's primary needs are for efficient and effective services delivery to very large rural populations, a large volume of supplies, and additional training in health care and program management.

In Latin America, some governments are reluctant in the face of religious and conservative opposition to give rigorous support to family planning programs, but public demand for family planning services is growing rapidly. As a consequence, support for private agencies and expansion of family planning within health care systems are increasing.

In the Middle East, the limitation of opportunities beyond childbearing for women is a major barrier to fertility change. Expansion of government and private services, and of broad social programs, is needed. The continuation of innovative efforts by private population and family planning agencies to change perceptions of the role of women is crucial.

Birth rates in some countries in Africa are the highest in the world, but few African countries have formulated policies that make a direct connection between their serious economic and social problems and rapid pop-

ulation growth. As most of these countries do, however, favor the provision of family planning services in the context of maternal and child health activities, emphasis should be on support for family planning as a component of health programs. Improved collection and analysis of demographic and other data would make an important contribution to increased understanding of the magnitude of population growth and its impact on economic development and the environment. Expansion of the role of existing private voluntary agencies would facilitate delivery of family planning services and improvements in maternal and child health.

There is thus a major difference between Asia, for example, where governmental programs are established but where support is needed to make them comprehensive and effective, and Africa, where there is much less appreciation of the implications of rapid population growth and less governmental commitment to extend family planning services widely.

These broad generalizations mask the variability that exists among countries, which is at least as great as that among regions. Different countries have different cultural values and development goals and thus require different forms of assistance. Different forms of government and different political alliances also make some forms of assistance more appropriate to one country than another.

Technical assistance and commodities for population planning and family planning programs are currently channeled through several major international agencies and many private nongovernmental agencies. The largest agencies, AID, UNFPA, IPPF, and the World Bank provide technical assistance in varying degrees in the areas of family planning services (including commodities); information, education, and communication; institutions and training; research and evaluation; policy development; and data collection.

Each agency tends to have different emphases and priorities within a broad range of support activities. For example, UNFPA provides technical assistance for basic population data collection, and channels assistance for family planning services primarily through health ministries incorporated into maternal and child health programs. AID is the largest supplier of commodities and places strong emphasis on family planning services delivery. IPPF emphasizes family planning services delivery in private sector clinic settings. Because each agency has different emphases and countries have different priorities, the agencies can cooperatively tailor their support to individual country needs.

About 28 percent of AID funds are currently dispensed to the multilateral agencies (UNFPA and IPPF), 26 percent are dispensed bilaterally, and 46 percent dispensed to and through private intermediaries and organizations. Changes in present proportions of assistance would have uncertain effects on the balance that has been achieved among these agencies and there are no compelling reasons for considering changes at this time. Given current shortfalls, duplication of efforts is not an issue, but if funds are increased, efforts to promote greater coordination among

agencies at administrative and country levels would need to be examined more closely.

Additional issues for congressional oversight

- Establishment of a single congressional mechanism for continued oversight of population issues.
- Review criteria for determining which countries receive population assistance and channels through which assistance is funneled.
- Review of U.S. priorities and restrictions in addressing global population issues, such as prohibition of aid to China.
- Consideration of ways to accelerate the pace of self-sufficiency in LDCs and encourage greater participation of the private sector in LDCs.
- Address the factors of product liability suits, shortened patent life, and FDA's export provisions on drugs, which may be inhibiting the development, manufacturing, and marketing of contraceptives and other medical products.

NOTE: Copies of the full report "World Population and Fertility Planning Technologies: The Next 20 Years" can be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

General Information

Information on the operation of OTA, the nature and status of ongoing assessments, or a list of available publications may be obtained by writing or calling:

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Mr. GIBBONS. Thank you, Mr. Chairman. As I mentioned in my testimony, OTA itself has not operated any of the major global models, but we have followed this work very carefully because we are interested in global models as a context for the more utilitarian specialized models that are more directly related to specific policy decisions. If you do not have that integrating context for individual models, then you can make some pretty costly mistakes.

OTA's work in population projections, for example, was not an independent analysis by OTA, but rather an integration of what we feel are the most thoughtful projections of population that have been made by other agencies. I refer you to the information on that in the population study. What OTA tried to do was give some additional information on how population growth might be affected by changes in fertility planning and by the technologies which we see on the horizon in the next 10 years or so.

So, we view the global models as a very important way to make sure that we are counting things properly, that we are not double counting resources, or that we are not leaving resources out, and that the assumptions made in one sector are consistent with the assumptions made in other sectors. Of course, that has been one of the criticisms of the "Global 2000 Report," namely, that different asumptions were made in different parts of this analysis. I think the authors themselves point out that this is one of the frailties or limitations which were associated with that study, and that follow-on studies surely would be able to improve in terms of making these internally consistent.

Mr. Chairman, you mentioned a little while ago the business of forecasting population growth and what its impact might have been on the U.S. social security system. I might mention another example that we have noted in recent years—the projection of demand growth for electricity in the United States. Not very much care was given to the forecasting process in demand growth during the early seventies when energy prices began to shift. A number of people expressed concern that the traditional models for forecasting energy demand were off, and that we were getting ready to over-invest in that sector. That has turned out to be the case, much to the cost and concern of a lot of people in the consuming sector. I know that this had led to a major controversy in the Tennessee Valley area, where inappropriate models were used to project demand and billions of dollars were committed to new powerplants. We now realize that not all of these plants are needed, and yet they have to be paid for by the people and by the power companies.

So, I think if one looks at the more specialized models in specific public policies, we find many opportunities to avoid very costly mistakes if we spend a bit more time and care in thinking both dispassionately and carefully about the future.

Senator MATHIAS. Let me defer to the Senator from Connecticut for questions.

Senator DODD. Thank you, Mr. Chairman.

Mr. Gibbons and Mr. Phelps, let me give you my apologies for not being here earlier. I wonder if one of you might give us some idea of the net cost of some of the more centralized Government statistical forecasting capability. Would there be some savings in your mind through the elimination—well, I guess I am telling you what I think

the answer is by my choice of words—the elimination of the duplication, as I see it, and the inconsistency of separate agency activities which only seems to create additional costs, but I would like to have your response to that.

Mr. GIBBONS. Senator Dodd, I share your conviction, as I understand it, that more effective interagency communication and coordination in this kind of work could have three effects. One would be a much lower chance of duplication of work or data gathering. Second, a much more effective use of the data by the separate agencies; and third, an opportunity to have a much more totally consistent picture across the agencies about the future.

One thing that was noted in the "Global 2000" study was that different assumptions about important trends, such as future population growth or GNP growth, were made by different agencies as they developed their separate studies. Might I ask Mr. Phelps if he would like to add to my response?

Senator DODD. Certainly.

Mr. PHELPS. The difficulty was not only in the kinds of data collected, but also in how that data was aggregated. One of the problems in trying to impose some kind of discipline in "Global 2000" was the fact that the Department of Agriculture and the Bureau of Mines, for instance, divide the world up into different regions, so there is no basis for comparison of their forecasts of the interrelations between those sectors.

Senator DODD. Just on the duplication itself, is there a lot of interagency communication at all that goes on? I presume there is a certain amount just by awareness of what others are doing, and so there would be some effort, I presume, to not duplicate, but is it really excessive? Is that a widespread problem?

Mr. GIBBONS. I cannot speak for the executive agencies, Senator. I have not worked in the executive branch for about 7 years. I know that it is always a problem to have effective interorganizational communications, and frequently you depend on third parties to assure that that cooperation and communication exist in the agencies of Congress. In the CBO, the GAO, the Congressional Research Service [CRS], and the OTA, we have instituted over the past several years frequent high-level meetings as well as working-level meetings, and automatic cross-notification of work, so that we have been able to absolutely guarantee that we are not doing, as it were, duplication of effort.

In working with the executive agencies from which we obtain much of our data, we have found little evidence of substantial duplication in terms of data. So, I think the problem may be very specific. I will have to apologize for not being able to answer for the executive branch.

Senator DODD. Of course, what we are trying to drive at here, and the chairman particularly, I think, because of his interest in this subject going back a number of years, is how we use models in the formulation of foreign policy. I wonder if you might share with the committee some examples of where modeling, where the use of models has had an impact on the formulation of foreign policy, going back, if you will, to your previous experience of some 8 years ago. I would like to get some sense of how this impacts on the decisionmaking process.

Mr. GIBBONS. Well, if I speak broadly of models rather than just the global models, I think we find a very mixed degree of utilization of

these techniques in the various agencies. It was my experience at the Federal Energy Administration, where I worked briefly, that there was a good deal of effort going into data collection and analysis, and into the construction and constant improvement of techniques of modeling, so that they were able to formulate national energy plans and the like using these models. I see this as a rather active, long-term activity. In the Department of Defense there is evidence of a substantial and growing use of rather complicated major models. Economic modeling has also been used by the Council of Economic Advisers as well as the Department of Commerce.

I think there is a bit more of a question with respect to foreign policy issues. AID does use some simple models of population growth and the like, but the extent to which the State Department is directly familiar with the current status and opportunities from major global modeling in assessing foreign policy is one that I am concerned about.

Might I ask Mr. Phelps again to add to that?

Senator DODD. I would like to know about the State Department particularly, since that is the principal agency responsible in this arena. What are their capabilities? I would be delighted to hear about the Department of Energy, too, though I am not sure we will have one for very long, but it is nice to know they have the capability. What about the State Department?

Mr. PHELPS. The two State Department models that I am most familiar with, sir, are the Rapid model and the Plato model, both of which are fairly simple population-sector models that are used to examine the effect of changes in population growth rates on the future availability of resources and the future economic development of individual countries. AID has used this with some effect in demonstrations for foreign governments—to demonstrate to the Government of Costa Rica, for example, that if their population growth rate were to decline, more of their forest resources would be available, both for domestic consumption and for export for foreign currency.

Similar demonstrations have been done by AID in a number of countries. I think they have been influential in affecting the policies of those nations.

Senator DODD. Have they been accurate? Do they have credibility? Have we had examples where our forecasting actually has been on target, and countries have benefited directly as a result of that awareness?

Mr. PHELPS. I do not think that they have been used to actually predict what is going to happen. The point in these forecasts was to demonstrate what would happen if a certain change in policy and population growth rates were to occur. It is a conditional forecast, used to demonstrate the effects of a specific policy change.

Senator DODD. You mentioned something which I would like to ask you about. Changing technology is a constant problem, something that we in Congress do not deal with very effectively. We are at best several light-years behind what is happening in the real world in the area of technology. It just occurred to me, what accommodations are made in the models to take into account changing technological advances? How do you adjust for that?

Mr. GIBBONS. You have to look at the assumptions made in the models. For example, in the "Global 2000" study certain assumptions

were made about a continuation of change of agricultural productivity on out in the future. Those assumptions have imbedded in them the implicit assumption that technology continues to advance, and therefore is the wellspring of this continued increase in productivity. You have asked a key question.

For example, in an input-output study of the world economy, if you are not careful about your assumptions on technology, you can forecast an exhaustion of critical resources which, in turn could lead to skyrocketing prices and international conflict. If, on the other hand, you look at it carefully and understand the substitutability of materials—modern composite graphite-fiber techniques, for example, compared to traditional metals—then the whole notion of what constitutes a critical or strategic material begins to change. You also begin to change your notions about future material shortages and resource shortages, and therefore international tensions.

The same is true for energy. If you make assumptions about energy growth that are inappropriate one way or the other, you are led to markedly different conclusions about the state of the world even 10 or 20 years from now. So, we feel in each of these models one has to be very careful to understand just what assumptions are being made about technology.

Senator DODD. Do you have any further comment on that, Mr. Phelps?

Mr. PHELPS. Yes, sir. The example of agricultural technology is a very good one. Often the global modeling studies will simply assume a kind of disembodied technological progress, assume that yields in the agricultural sector will increase by 1 percent a year, without examining precisely which technologies are going to be necessary to accomplish that increase, whether that technology will be available to the country that is being examined, and whether that country will be able to apply that technology—whether they can afford the inputs. This has been one of the reasons for the failure of the Green Revolution: The price of fertilizer has gone up far more than expected, and the momentum of increased yields has been lost.

Very often the assumptions about technological progress do not examine what the possible environmental consequences of a misused technology might be. Perhaps the most useful function of the models and the process of modeling and talking about the assumptions that go into them is simply to air these questions, to force people to examine the assumptions they are making about contributions that might come from technology.

Senator DODD. You mentioned the State Department, the Pentagon and the Department of Energy as three agencies that have modeling capabilities. What would be your thoughts, and I ask this of both of you, although I am reluctant even to bring this up—I feel like I am a C.P.A. since I have arrived at the Senate. I have spent my time on the first budget resolution, then the second budget resolution, then I go home. [General laughter.]

What would your advice be if someone were to recommend that Congress might have developed some modeling capability in this area? Would we be taking on a task that really would be too large for the institutional when compared with other obligations? Or do we have a capability in OTA, CBO, and other organizations, the existing in-

place arms of the Congress, if you will, that would make it possible for us to do that without any substantial increase in the congressional burden.

Mr. GIBBONS. It strikes me that it is very important for the legislative branch to maintain its own independent capability to judge and to critique information being provided to the Congress by the executive branch or from the private sector. To that end we at OTA, our colleagues at the Congressional Budget Office, and other of the legislative agencies do have the capability, I believe, to critique and be knowledgeable about models.

We do not have the capability, and I am not sure that we should, to develop the models themselves. Rather, we would utilize them. We use models that are in existence at the national laboratories or in the private sector. We have to have the in-house expertise sufficient to know just what we are working with, and not to play with black boxes.

On the other hand, in the executive branch, it seems to me that there may well be a rationale for attempting to provide to Congress and the Nation—and as I mention in my testimony perhaps on a biennial basis—a review of the status of the methods and of the state of the art of modeling and its implications for the United States in its broad responsibilities.

So, I would see the legislative branch in terms of playing the westerner riding shotgun with the executive branch where they support the development of fundamental modeling methods and try them out and test them out and report upon them. Within the legislative branch, I see a continuing need to know about these models in sufficient detail to be able to critique them, exercise them, and give them independent judgment.

Senator DODD. There is nothing to preclude Congress at this juncture, as you are suggesting, to utilize the existing modeling capability of other agencies.

Mr. GIBBONS. That is right.

Senator DODD. Do you get requests or have you had requests from Congress to take advantage of those capabilities or are the requests nonexistent?

Mr. GIBBONS. We have exercised a number of models, as I mentioned, Senator Dodd, that were developed in the executive branch, and we have utilized those models in fulfilling requests for information from the Congress. One of the more recent requests, for instance, has been the effects of various proposed changes in the Clean Air Act on the cost and on the effectiveness of various cleanup strategies in the United States, State by State, and the consequent impacts downwind.

In doing that work, we exercised quite extensively some models, most of which had been developed by executive branch agencies and were available to us from the national laboratories or other parts of government. We do not solely depend on that, but we do depend quite heavily on that.

Senator DODD. Did you want to comment, Mr. Phelps?

Mr. PHELPS. I have nothing to add, sir.

Senator DODD. I know that I speak for all of the members of the committee when I thank you, and I want to apologize for Senator Mathias, who had to step out for a few minutes and was unable to be here for your testimony. On behalf of the committee, we do appreciate your

being here today and your responses to our questions. We look forward to working more closely with you. I hope we will take advantage particularly of what you have just suggested. Maybe if Members of Congress are more aware of the availability of modeling, there might be more direct requests to utilize that capability at the Federal agency level, particularly in foreign policy matters.

As I was listening to your last statement and commentary, I have particular interest in the land reform issue in El Salvador, and I do not know whether we have the capability at the State Department or other agencies to examine what the proposed changes in land reform would mean in terms of agricultural production, utilization of arable land in that country, and trying to help us formulate foreign policy that would reflect not only our own interests but the interests of the region, and obviously the people of El Salvador.

I do not know whether that kind of capability exists, but it seems to me if we can do that more accurately in the future, then we can develop a foreign policy that is going to be more predictable, more consistent, something about which we can feel more comfortable as we move forward into areas that are at the very least amorphous.

So, thank you.

Mr. GIBBONS. Thank you, Senator.

Mr. PHELPS. Thank you, Senator Dodd.

Senator DODD. I will deviate a bit from the schedule for today as it was announced, and will ask Hon. Elliot Richardson and Mr. Gustave Speth, president of the Institute for World Environment and Resources, Inc., to come to the witness table. I will call on Mr. Hill at the conclusion of the testimony of our public witnesses.

Mr. Ambassador, I love seeing you as a public witness, considering your contributions to this country over the years. I am honored that you are here. Elliot Richardson has made more contributions to this Nation in a relatively brief period of time than most Americans. We are honored that you are here this morning to offer testimony and comment on the subject matter before us, global trends in population and resources. I know I speak for Senator Mathias, who will be here briefly, when I say that we are grateful to both of you for being here.

If you have prepared statements, I would be happy to read them and will accept both of them for the record.

I would point out, of course, that Mr. Speth has served as President Carter's chairman of the CEQ, which produced the "Global 2000" study. We are all deeply indebted to you and to your colleagues for developing that study, which really has provoked the many, many questions that you have heard today and will be hearing for some time to come, I would imagine.

On behalf of the committee, I welcome both of you, and would be delighted to receive your testimony.

STATEMENT OF HON. ELLIOT RICHARDSON, WASHINGTON, D.C.

Ambassador RICHARDSON. Thank you very much, Senator. I appreciate very deeply your very generous words. I can only say that I have always enjoyed the opportunity to appear before this committee and its subcommittees, and have gained, I think, over the years some appreciation of the enormous difficulties of dealing with the issues of

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policy that you address. The one that this subcommittee has been convened to consider is, in the most fundamental sense of the word, global and, therefore, abstract, hard to get at, and easy to subordinate to the most immediate pressures of today and tomorrow.

Indeed, the set of questions that you have addressed suffers continually from the consequences of the truism that the immediate drives out the important. As to the importance, it seems to me that the conclusions expressed in the Office of Technology Assessment report, "Global Models: World Futures and Public Policy," under the heading of its discussion of the world integrated model, very succinctly put, the answer to the question, Are global models useful? These conclusions which appear on page 23 are the current crisis in agriculture, energy, et cetera, are not transient but persistent and represent the first signs of an oncoming era of scarcity.

The solutions to these crises cannot be found through isolated, short-term, or narrowly nationalistic strategies, but only through an integrated global context and in the spirit of truly global cooperation guided by a rational master plan for long-term organic growth. And the time that can be wasted before developing such a global world system is running out.

These conclusions can be restated in terms of four rather obvious propositions. But unfortunately, the fact that a proposition is obvious does not necessarily mean that it is understood, or that if it is understood, that it is felt and acted upon by people whose imaginations as well as whose intellects have been engaged by it.

One of these is that the discernible trends identified by all efforts to discern the shape of the future are having irreversible impacts, and if they were projected far enough, these impacts could be very serious, even disastrous.

Second, to check if not to reverse these trends requires long lead times, and this, in turn, means, therefore, that there must be the sustainable capacity to follow through with the decisions that have been made about how to address them.

A corollary of this, the third point, is that the policymaking process must be capable of very hard choices about how to allocate resources among the competing claims of the long-term foreseeable future. That requires a degree of rigor and honesty in addressing this kind of question that is all too easy to evade. The Arkansas traveler syndrome affects civilizations as well as individuals.

Finally, there will be involved massive amounts of capital, amounts indeed which only point up the necessity both for rigor in facing the requirements of choice and the importance also of securing the maximum amounts of lead time in order to make rational plans for the allocation of capital resources as they come available over a substantial period of time.

All of these considerations, it seems to me, point clearly to the conclusion that global models are useful if only in order to give warnings of what will probably occur if policymakers do nothing.

If, of course, the projected trend is benign, or if it is not so bad as to bother us much, we would presumably choose to let it alone. But even then we need to recognize that those trends that we do not relish and would like to avert and which thus stimulate intervention may result

in intervention which will affect the long-term trends that we would just as soon let run their course undisturbed.

Every form of intervention for the purpose of preventing what we do not want to have happen can have side effects on those things that we had not intended to change. The necessity, therefore, to take heed of the warnings available to us and to analyze the implications of intervention both point to the usefulness of models.

It should be emphasized, of course, and it has no doubt been emphasized by others, that the projection of a trend is not a prediction. The function of the model is to project the visible trends in such a manner as to take into account as best we can the interaction among all the visible trends. And then, of course, to the extent that we assume futures in which there are variations among the relative impact among trends, we can at least in principle use the model to test the possible consequences of variations in policy or varying allocations among resources.

The better the model, the better the judgment that can thus be made. I think it is particularly important for a government—and here I would refer to the policies of the United States under both political parties—that seeks to minimize government intervention and maximize reliance on private decisionmaking to have this kind of foresight capability.

The less we care about government intervention—that is, the less we care about how massive and pervasive it is—the less we need to worry about the side effects of intervention. The price in the Soviet system has already been paid for taking total control of the society, including its economy. If a mistake is made, therefore, the mistake can be corrected by adjusting government policies. There cannot be any more intervention than has already occurred.

But in the case of a society that values its freedom and thus seeks to minimize intervention and that has an increasing compelling need to minimize intervention as the society grows more complex and the demands for intervention multiply, it becomes much more important to understand the consequences of intervention.

We have seen over the last couple of decades, in particular over the most recent one, the reactions to the unforeseen consequences of Government policies that had effects that no one anticipated. The results has tended often to be that the Government has had to intervene further.

Take the simple example of school integration. Everyone, I think, certainly today, would recognize that *Brown* v. *Board of Education* simply expressed fundamentally valid values of the society; we could not countenance the continued segregation of schools on a basis consistent with our affirmation of belief in the individual dignity and worth of all citizens.

So we started out by taking half the children in a black school and sending them to an all-white school and taking half the children in an all-white school and sending them to the previously all-black school.

Then we began to worry about whether or not the classrooms within the schools were integrated, and we had to look inside the classroom to see, and so on, down to the question of whether or not the Government had an obligation to make sure that the cheerleaders and the bands were integrated.

The problem in every such case is one of trying, if you can, to see ahead to where the initial steps are taking you. I think it is fair to say that to the extent that we want to preserve a role for the private sector, both government and the private sector have a greater need to understand the way the system works and how things interact within it.

So a capacity to project trends is inevitably therefore a capacity to see the interaction among trends. And since government policies are, by definition, designated to affect what would otherwise be the course of a trend, what you have then, to the extent the quality of the model is progressively improved, is an ability to test what may be the consequences of various alternative claims for government intervention.

Let me turn next to the question of the utility of this kind of capacity for the formulation and conduct of U.S. foreign and national security policy. It seems to me quite obvious that it does have relevance and utility. The foreign policy and national security problems of the future are, to be sure, in large part likely to derive from relatively sudden, rapid, even impulsive actions that would have been impossible to predict and difficult to guard against, although I think it is fair to say that we could do a better job than we do in contingency planning against the certainty that certain kinds of irrationality will occur. But there are other kinds of developments, demographic and economic, that certainly do have relevance insofar as U.S. long-term foreign and national security policies are concerned with global stability.

It seems to me that this point needs relatively little elaboration. A possible example is the case of El Salvador. In that country, as forests were razed to meet the agricultural and fuel wood needs of the population, soil erosion undermined the productivity of El Salvadoran land. As the nation's agricultural base diminished, economic hardship set in. Extreme political instability followed and precipitated costly U.S. military involvement.

Had the trends toward overpopulation, deforestation, and soil erosion not been ignored, might El Salvador's deterioration have been avoided and U.S. military expenditures obviated? We do not know. But we can presume a link between natural resource trends, economic hardship, and political instability. I am sure that many other examples could be cited.

But apart from the purely prudential considerations that should motivate us, it is certainly relevant for the American people to consider how we would feel living in a globe in which the present trends had resulted in a situation in which we were five times relatively richer than the poorest people in the world than we are now, consuming a still higher share of total global resources, in a sea-surrounded enclave fighting off any sense of responsibility toward the rest of the world.

It seems to me quite clear that Americans would feel a sense of betrayal of their own values in such a world. Whether you call the responsibility to try to prevent such a world moral or whether you think of it simply in terms of buying a degree of peace of mind and a sense of satisfaction with being alive, seems to me relatively unimportant. I cannot see the United States claiming the worth of its traditions, values, and example, purporting to exercise leadership for the preservation of a peaceful, stable, orderly world and at the same time

turning its back on the effort to prevent the direst of the consequences that could occur if we do nothing.

May I just add finally, Mr. Chairman and Senator Dodd, that I am here this morning as a representative of the year 2000 Committee. This committee, as I think you know, grew out of the report that my distinguished colleague and friend Gus Speth and others produced. And it exists in order to try to develop a sharper focus of attention on the need to address these questions.

The cochairmen are Russell Train and former ARCO chairman Robert Anderson. Among its members are Bill Ruckelshaus, Bob McNamara, Cy Vance, Henry Schachte, and Walter Cronkite. While I am not testifying directly on their behalf, I doubt if I would have been asked to testify at all but for the fact that I am a member of that committee. Thank you very much.

Senator MATHIAS. We thank you very much for being here and for a very thoughtful statement. I apologize for being momentarily out of the room when you came to the witness table. I had previously announced that you were going to be here because of the fact that you are the only known Cabinet member in the "Guinness Book of Records."

Ambassador RICHARDSON. Well, I am glad to know that I am in the "Guinness Book of Records" for something. [Laughter.]

Senator MATHIAS. Well, you are the only person in American history who held four Cabinet posts, according to the "Guinness Book of Records."

Ambassador RICHARDSON. I bet I will long hold the record of having held the four Cabinet posts in a given period of time. Maybe somebody will beat the record otherwise. [Laughter.]

Senator MATHIAS. Had I been here when you came to the table, I would have greeted you as I normally do, as Ambassador Secretary General Richardson. But I think what you have done is make a distinction between planning and the socialist pattern of planning and the capacity to know what is to be known about the future and taking prudent decisions as a result. That is a very big distinction, but it is one that is sometimes lost when people think about the trends.

Ambassador RICHARDSON. Exactly.

Senator MATHIAS. Second, I think we do need to talk a little bit more about how this possibility can be applied in the foreign policy field. If we can get some idea of what is happening in South America, which is an area of great interest to Senator Dodd, for example, how should that affect our foreign policy today, which, as we have just seen in the Falklands episode, is centered on the North Atlantic, but what is the South Atlantic going to be in its relative relationships and its relative position in the world 50 years from now and how should that affect what we are doing today?

I would suggest, if I might, for Mr. Speth to give us his statement, and then we could have some conversation which would include him. But before he starts, let me welcome to the committee the distinguished Governor of Puerto Rico, who has joined us momentarily.

Mr. Speth.

STATEMENT OF JAMES GUSTAVE SPETH, PRESIDENT, INSTITUTE FOR WORLD ENVIRONMENT AND RESOURCES

Mr. SPETH. Mr. Chairman, thank you.

I will be very brief, because I know you are interested in asking questions.

My experience as chairman of the Council on Environmental Quality and other experiences that I have had before and after led me to the conclusion that we needed a new institution in the United States, a think tank, if you will, that will carry out policy analyses, policy studies, and policy research on this range of global resource and environmental problems that we have been discussing here this morning.

As a result of that and similar realizations by a number of other people, we did create a new institution, which we have called the Institute for World Environment and Resources. And I'm happy to be able to report this morning that we were successful in receiving a major grant from the MacArthur Foundation in Chicago, which will provide most of the funding that we need for this new institution that will address these issues, as well as the foresight capability that you were concerned about in a partial way.

The agenda that our new institution will address is an agenda which is increasingly widely shared: The problems of agricultural lands loss, deforestation, species loss, an accumulation of carbon dioxide in the atmosphere, transboundary pollution problems, toxic chemicals, nonfuel minerals and other problems, which we share with other nations on the globe.

We will be actively engaged in the months and years ahead in the study of these issues as they relate to policy. We will try to bring the best scientific information and other information available to those questions in an effort to develop policy options that will be of use to, we hope, the policy community in government and the policy community in the private sector.

Our focus will be principally on those communities in the United States, but certainly not exclusively. We do hope to produce materials which will be useful to international organizations and to other governments and corporations abroad as well.

And Mr. Chairman, with your permission I would like to submit for the record a longer description of the new institute and what we hope to do.

Senator MATHIAS. Without objection, your full statement will appear in the record.

Mr. SPETH. Fine.

The two things that the committee has asked specifically that we focus on are, first, this question of foresight and global models. I have had an opportunity to review the OTA report that Jack Gibbons presented to you this morning, and am eager to say that I am in general agreement with each of the four actions discussed in chapter 5 of that report.

More generally, it seems to me that there is increasingly wide agreement on three points. The first is that a necessary predicate to intelligent public and private responses to these long-term resource and re-

lated problems is foresight, including the ability to carry out reliable qualitative and quantitative analyses and projections of trends.

The second point is that there has been great room in the past and extending up to today for valuable improvements in the Federal Government's programs for gathering data and other information in these areas and for using this information in modeling and predictions.

And third, to bring about this improvement a focal point should be created within the Federal Government, probably within the Executive Office of the President, to work with Federal agencies and others, including the private sector, first, to insure availability of adequate data and modeling capability relating to global resources, environment, and population problems; and second, to promote any increased use of this capability in studies helpful to policymakers.

Mr. Chairman, you have also asked about how these current trends might affect U.S. foreign policy and security policy in the future. One concern is the effect that future developments in population, resources, and environment can have on our national security, broadly defined. Obviously, our security depends on factors in addition to our military position. Shortages of oil and strategic minerals can affect security. But the more indirect consequences of possible future resource and environmental developments may be just as important.

Many of the forecasts now available see the possibility of a considerable tightening of resource availability in the decades ahead, particularly availability per capita, with heightened vulnerabilities in the international community and new opportunities for shortages, disruptions, and tensions, both within and among nations.

It is impossible to deal briefly with subjects of such great complexity. But I believe these relationships deserve increased attention, and the forecasts on which they are based also deserve attention. The general question of the long term security implications for the international community of these trends is, it seems to me, of great importance.

Thank you.

[Mr. Speth's prepared statement follows:]

PREPARED STATEMENT OF JAMES GUSTAVE SPETH

I. GLOBAL RESOURCE AND ENVIRONMENTAL ISSUES

Throughout the past decade, a number of reports—from the United Nations, the World Bank, the International Union for the Conservation of Nature and Natural Resources, the United States Government, the U.S. National Academy of Sciences, and many other organizations—have sounded a persistent warning. severe stresses on the earth's resources and environment are apparent. With increasing human demands and inadequate attention to resource issues, the possibilities of further stress and permanent damage to the planet's resource base are very real. To improve resource management, to restore and protect the earth's capacity to support life and meet human needs, is an enormous challenge.

These concerns have not just been discovered as global problems. The United States and other nations have recognized them and made efforts to deal with some of them. What the recent reports do emphasize in a new way are the pace and scale of the problems and their interrelationships--the web of causes and effects that bind them together.

Another fresh insight is the degree to which the earth's renewable resources are under threat. In the past decade, international attention has fastened on whether global supplies of finite nonrenewable resources, especially oil and non-fuel minerals, can meet the growing needs of an expanding world population. Just as important, the recent reports tell us, is to maintain the health and productivity

of the earth's natural systems—the air and water, the forests, the land—that yield food, shelter, and the other necessities and amenities of life.

The capacity of some global regions to support human populations is already being seriously damaged by efforts of present populations to meet immediate needs. The spread of desert-like conditions due to overgrazing and other factors now claims an area about the size of Maine each year. Desertification and erosion could destroy a significant portion of the world's cropland by 2000. Some estimates suggest that as much as 20–40 percent of our tropical forests may be gone by then. Deforestation in the tropics and elsewhere accelerates erosion and siltation and contributes to floods, droughts and diminishing supplies of fuelwood and other forest products. It and other changes also threaten an unprecedented loss of hundreds of thousands of irreplaceable plant and animal species. Decades of patient wildlife conservation efforts can be undercut as pressures on habitat increase, but the loss of species has another dimension as well. These species represent a major economic resource—a new source of pharmaceuticals, foods, pest controls, and chemicals and materials such as woods, fibers, oils, resins and dyes—and their economic importance is increased with the advent of genetic engineering technologies.

While productive renewable resource systems are clearly essential to the support of human life, keeping these systems productive over the coming decades will require painful, even tragic, choices. A fishery, for example, can provide a certain amount of food indefinitely, or a larger amount for a few years. Management of fisheries is a widely accepted practice, but the analogous management of topsoil—to use just one of many possible examples—is not. The United States may soon have to face the technical, economic and moral dilemma posed by the necessity of preserving its long-term agricultural productivity at the expense of lower production in the short-term. Dozens of similar choices will confront every nation and region of the globe.

The recent reports also bring out that economic development of a sustainable nature, far from being antagonistic to protection of global resources and the environment, is absolutely necessary to its success. Such development is essential to interrupt the cycle of poverty, population growth, and environmental degradation that is putting unsupportable pressures on croplands, pastures, forests, and fisheries in much of the less developed world.

The stresses on renewable resources, while most acute in the developing countries, are not confined to them. For example, in recent years the United States has been losing about 3 million acres of rural land annually—including 1 million acres of prime agricultural land—due to suburban sprawl, highways, and other developments. Each year we are also losing the equivalent, in production capability, of as much as 1 million more acres due to soil degradation—erosion and salinization. About 225 million acres in the United States, mostly in the Southwest, are classified as undergoing "severe desertification" today. Recent reports emphasize the serious worldwide nature—in rich countries as well as poor—of the degradation and loss of agricultural land. Loss of fresh water supplies due to poor management and pollution is another serious problem the United States shares with many other regions of the world.

These planetary-scale issues, and others such as acid rain, toxic chemicals, and the "greenhouse effect" stemming from the buildup of carbon dioxide in the atmosphere, are discussed in greater details at various points in this document and particularly in Section V.

The United States, with a seeming wealth of resources at its command, nevertheless has good reason for concern about global resource stresses and environmental degradation. We share with the rest of the world a profound human interest in protecting the earth's resources for generations to come, in achieving patterns of resource use that can support sustainable economic development, in protecting public health, and in preserving the vitality, beauty and diversity of the natural world. There are also impelling reasons of self-interest for concern about these problems. U.S. political and economic security, and that of other countries as well, is already being affected by global resource, environment, and population problems—more so than is commonly understood. The effects are likely to become greater with time, if present trends continue.

II. ROLE OF POLICY STUDIES IN ADDRESSING GLOBAL RESOURCE AND ENVIRONMENTAL CHALLENGES

Many things need to be done if the United States is to meet successfully these national and global challenges. As the United States and other nations focus attention on these issues, a premium will be placed on:

Accurate information about global conditions and trends and about possible effects of global environmental alterations on health and welfare; sound scientific and technical evaluation; careful analysis of alternative policy responses; understanding trade-offs between long-run and short-run considerations and between United States and other interests; inventive approaches and the wider use of incentives; and better public understanding so that correct political choices can be made.

This need for more knowledge, better foresight and sophisticated analysis points clearly to the need for a solid policy studies capability in this area.

The overall importance of policy studies in government and in the private sector is increasingly appreciated. Those close to the development of national policy during recent Administrations have seen the way that such studies have had an important impact on policy. Several policy studies are frequently mentioned as having been timely and effective in influencing policy: the public lands law review, the Ford Foundation nuclear energy study, the reports on ocean dumping and toxic substances control by the Council on Environmental Quality, and the recent National Academy of Sciences report on acid precipitation. On the other hand, the lack of timely, effective policy studies on, for example, moving Alaskan oil south and on disposing of nuclear waste resulted in mistakes or lost opportunities.

When properly done, policy studies can:

Identify emerging issues, and illuminate where we are headed; raise the level of debate, sifting points on which there is consensus from those on which there is real disagreement; identify further research that must be done before informed choices can be made; develop innovative policy alternatives and creative approaches to problems; and raise awareness of options and their consequences, and rally interest here and abroad.

The first of these points stresses the value of policy studies in providing an "early warning system" that can recognize problems before very costly or irrevocable mistakes are made. But it is also important to see policy development as a continuing process, involving successive deliberation and revision as more is learned. In this way, the policy studies process, in particular the organizations that produce the studies, can provide an invaluable institutional memory.

A distinct justification for involvement in the studies is the need to improve the approach and style of policy studies themselves. For example, policy studies to date have suffered from not having the strongest scientific and technical grounding and from not having sufficient disciplinary scope. Too often scientists and other experts are consulted only at particular times or for narrow purposes during a policy study, with the unfortunate result that the creative and inventive suggestions that can come from sustained involvement are missed.

A related goal that could improve the caliber and effectiveness of policy studies is to better integrate "head and heart," that is to marry technical and economic information with careful consideration of values that are difficult to quantify. Policy studies should explicitly consider different sets of values and examine how various policy options relate to these values.

Finally, policy studies need to reflect greater awareness of the policymaking context in which they are intended to operate. More attention should be paid to distinguishing technical from political issues and facts from opinion, and to translating scientific information into options suitable for the political process. Timing, style of presentation and language, and the follow-up that injects the study and its perspective into the process of actually making decisions are all essential.

At its best, the policy studies process can provide a more intellectually rigorous and analytical basis for policy decisions. From this perspective, the important role of private, independent support becomes clear. Such support is essential to increase the odds (1) that a problem will get identified and analyzed early enough, (2) that the alternatives will be openly and honestly formulated and explored on a plane where narrow interests and parochial concerns do not dominate, (3) that the public and decision-makers will have the benefit of some of our best experts and most innovative thinkers, and (4) that the results will have credibility with a wide audience. It is an unfortunate reality that some good studies are discounted because their sponsors are deemed to have a special interest in a particular outcome. There is therefore a real need for a sponsoring institution which has an overriding interest in the protection of its own intellectual integrity.

III. THE INSTITUTE FOR WORLD ENVIRONMENT AND RESOURCES, INC.: AN OVERVIEW

A. Concept and approach

The Institute for World Environment and Resources, Inc., has been established to fill the important need for an independent center for policy research, analysis and prescription—a major environmental and resources "think tank" for lack of a better term—that would help to formulate policy on the difficult issues of global importance that lie ahead.[1]

The Institute will be distinctive in important respects, including the following:

The Institute's commitment to a global perspective and to developing a better understanding of global resource, environment and population problems and what can be done about them will be unique. The Institute represents the first major commitment of its type to them.

Through a "hub and spokes" structure, the Institute will work with associated academic and research centers of excellence. The relationship between "hub" and "spokes" would not be rigid but open to development and evolution in an organic way. Through this structure, the Institute will tap underused intellectual resources, broaden the range of participants in public policy debates, avoid duplication of effort, and in the process help give coherence to a new community of scholars concerned with global resource and environmental issues.

The Institute's strong base in the sciences—both life and physical sciences—is a third distinguishing characteristic. This commitment to strength in the sciences will sharply increase the resources available for truly interdisciplinary policy research and analysis in the global resources field.

The significant size of the Institute (as proposed) will allow it to undertake projects and programs of large scope and potential impact, with strong technical depth, and the ability to produce relevant information at the right time in the right place without unduly long leadtimes.[2] The size of the Institute will also permit it to develop the reputation and stature in the United States and abroad that would enhance its effectiveness.

The Institute's relative permanence, interdisciplinary staff, and network of associates will enable it to identify important issues for study before they reach a crisis. Thus, the Institute will produce policy studies in time to be of use to policymakers and the public. Studies undertaken at an early stage of policy development will be modified, refined, and brought up to date, in light of new knowledge, extended public debate, and further understanding.

The Institute will guard its independence and credibility by avoiding an activist orientation or political involvements. It will not, for example, undertake lobbying, lawsuits or formal administrative proceedings or engage in for-profit activities or have large financial dependence on government.

Finally, the Institute will operate with the goal of being relevant to policy decisions, particularly those of the U.S. Government and other U.S. institutions. It will address issues that are, or should be, policy issues and do so in a way that is useful to policymakers.

The Institute will maintain the highest standards of objectivity and competence in its studies and publications. Rather than be at the center of each policy debate, it will endeavor to prepare the way for the next policy debate. Its approach will be lively and pragmatic, but not ideological or adversary.

In part, the Institute will serve as a bridge between scholarship and public policy, bringing the best scientific and other knowledge and analysis to the attention of decisionmakers and the public generally, while at the same time affording scholars better access to the decision process.

In its studies and analyses, the Institute will seek to avoid common pitfalls, such as being empirical to the point of neglecting values or normative to the point of neglecting available data. Ways to make explicit and address values, intangibles and risks will be explored, as will means to present and weigh information relating to environment and resources that is not now quantified.

The Institute will also serve as a forum where contending forces and ideas can be explored through participation in seminars, conferences and informal discussions. This ability to promote a dialogue both directly between involved individuals and in print will be a valuable asset.

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[1] The Institute is a not-for-profit Delaware corporation. Appropriate rulings are being sought from the Internal Revenue Service establishing the Institute as a charitable, educational, and scientific organization tax exempt under section 501(c)(3) of the Internal Revenue Code and tax deductible under section 170(c) of the Code. Tax counsel to the Institute is Thomas A. Troyer of the firm of Caplin and Drysdale, Washington, D.C.

[2] At maturity the Institute will operate on a budget of about $4 million a year.

In sum, the new Institute will:

Conduct policy research and develop and analyze alternative policy options; carry out a vigorous program of writing and publishing, sponsoring seminars and conferences, and other activities; work with government officials in the United States and abroad, with the media, and with private organizations and corporations; and encourage the development of new basic knowledge in support of the development of appropriate policies.

All with the objective of addressing in a timely and positive way the interrelated global resource and environmental problems that this country and others will face in the decades ahead.

B. Organization and networks

In pursuing these goals, the Institute will seek ties with many segments of American society and with those sharing similar interests abroad. University-based programs and relevant programs based elsewhere are important in this regard. A wealth of talent, ideas, and resources exists in our academic institutions that should be more involved in, or have greater access to, the policy process. As indicated earlier, the Institute will establish formal and informal relationships with university-based and other organizations to help bridge these gaps.

One set of closely affiliated groups will be the "spokes" in the Institute's "hub and spokes" organization. The hub will be the operating center of the Institute, with an interdisciplinary staff that will produce timely, synthesizing studies and analyses, and the spokes a network of associated groups, strong in the sciences, lodged in their own universities and laboratories, who will regularly visit and otherwise work with and contribute to the core institution.

The Institute Center.—In addition to the Institute's executive officers, the Institute center will consist of a core staff, shorter term project staff, and the group of distinguished fellows. The staff and fellows will be a group of impressive professionals, many of national and international reputation. While the center will have strength in the sciences, both natural and social, it will focus as well on attracting individuals with knowledge of institutional considerations and with strong policy backgrounds and records of effectiveness in the national and international policy arenas.

At any one time, a large portion of the Institute's staff will be project directors and associates working at the Institute on specific studies and projects. Affiliated "spoke" organizations will be an important source of staff and advisors for these projects. At the end of a project, some of the project staff might leave and others remain. A valuable characteristic of the Institute will be the provision of continuity and institutional memory in the discussion of issues relating to these global problems.

An essential component of the Institute's operation will be its Fellows Program, through which a group of creative and energetic thinkers will be brought to the Institute from around the United States and abroad. They will typically be selected because of the contributions they can make to the Institute's program and to the public dialogue on global issues. Fellows will be sought from the affiliated organizations and from universities, government, business and environmental organizations. Their stays can be as short as a year or as long as a few years.

The Washington, D.C., location of the Institute center has much to advocate it. It facilitates access both to critical information and to policy officials, allows the institute to attract the highest quality people from the United States and abroad, and has other advantages.

Institute Networks.—The other major components of the Institute's organization are the (1) affiliated national organizations, (2) affiliated foreign and international organizations, and (3) the networks of formal and informal participants, advisors and peer review panels. Building these networks of affiliated organizations and individuals is a priority objective of the Institute. They are essential to ensuring the quality, credibility and broad acceptability of the Institute's products.

The closely affiliated organizations here and abroad will comprise the "spokes" of the Institute's hub and spokes structure. Five or six U.S. organizations will be affiliated with the Institute as spokes at any one time. Each will be a center of excellence and will contribute importantly to the Institute's program through assisting in the identification of priority projects, providing relevant studies and analyses as well as key personnel, and acting as advisors on Institute projects. A portion of the Institutes' funding would be made available to these U.S. spoke groups to support Institute-related work there. The purpose of this support would

be to facilitate their interaction with policy issues and analysis and rarely to support basic scientific research. A majority of the spokes would provide a firm grounding in the biological and physical sciences; others would be selected for their strengths in foreign and economic affairs.

An initial effort to identify outstanding national groups to affiliate with the Institute has been undertaken. As a result of this effort, the following groups were selected, and each has expressed a strong interest in affiliation with the Institute:

The Center for Energy and Environmental Studies at Princeton University, headed by Robert Socolow; the Ecosystems Center of the Woods Hole Marine Biological Laboratory, headed by George Woodwell; and the Energy and Resources Group at the University of California at Berkeley, headed by John Holdren.

A network of affiliated organizations based in other countries (and perhaps international organizations as well) will also be established, although here the relationships would be less formal and intense. The United Nations University has offered to help identify these institutions and to encourage their participation. The United Nations Environment Programme and the International Union for the Conservation of Nature and Natural Resources (IUCN) will be consulted as well. Geographical distribution will be a factor in selecting groups abroad; an effort will be made to establish ties with at least one group in South America, Africa, South Asia, Europe, and the Middle East.

Finally, the Institute will seek to establish a network of leading individuals located in the United States and abroad. Representing all relevant fields and disciplines, these individuals will become involved in the work of the Institute in many ways; as fellows, as shorter term staff members on Institute projects, as paid consultants and informal advisors, and finally as members of formal advisory panels for major Institute projects.

IV. INSTITUTE LEADERSHIP: BOARD OF DIRECTORS AND OFFICERS

The Institute is fortunate to have a unique governing body—a board of directors that may be unprecedented in its diversity of backgrounds strength and relevance of experience and international prominence. The founding board consists of national and international leaders—scientists, conservationists, businessmen, diplomats and others—who have come together with a common intent: to build an institution that can provide sound analysis and policy guidance in the face of a terribly complex and disturbing set of world problems.

The members of the Institute's board at present are as follows:

Matthew Nimetz, Chairman—Partner, Paul, Weiss, Rifkind, Wharton and Garrison; Former Under Secretary of State for Security Assistance, Science and Technology; Trustee, Williams College.

John E. Cantlon, Vice Chairman—Vice President for Research and Graduate Studies, Michigan State University; former Chairman National Academy of Sciences Environmental Studies Board; former Chairman, Environmental Protection Agency Science Advisory Board.

James Gustave Speth, President—Institute for World Environment and Resources; currently Professor of Law, Georgetown University Law Center; former Chairman President's Council on Environmental Quality.

Robert O. Blake—Senior Fellow, International Institute for Environment and Development; former United States Ambassador and Assistant Secretary of State.

Soedjatmoko—Rector, United Nations University Tokyo; former Senior Advisor, Indonesian National Development Planning Agency.

William J. Baumol—Professor of Economics, Princeton and New York Universities; former President, American Economics Association.

Carleton D. Burtt—Executive Vice President, Equitable Life Assurance Society; Board of Directors, Overseas Development Council.

John E. Bryson—Chairman, California Public Utilities Commission; former Chairman, California Water Resources Board.

Adrian W. DeWind—Partner, Paul, Weiss, Rifkind, Wharton and Garrison; former President of the Association of the Bar of New York City.

John Firor—Director, Advanced Study Program, National Center for Atmospheric Research (NCAR); former Executive Director, NCAR; former Chair, Space and Terrestrial Applications Advisory Committee, NASA.

Donald Kennedy—President, Stanford University; former Commissioner, Food and Drug Administration.

Alan R. McFarland—General Partner, Lazard Freres & Co.; Director Dome Mines, Ltd.

Robert S. McNamara—Former President, World Bank; former Secretary of Defense.

Ruth Patrick—Honorary Chair and Senior Curator Division of Limnology and Ecology, Philadelphia Academy of Natural Sciences; Member, National Academy of Sciences.

Nathaniel P. Reed—Executive Vice President, Hobe Sound Company Florida; former Assistant Secretary of the Interior.

Russell E. Train—President World Wildlife Fund—U.S.; former Administrator, U.S. Environmental Protection Agency; former Chairman, President's Council on Environmental Quality.

Arthur C. Upton—Chairman, Institute of Environmental Medicine, New York University Medical Center; former Director, National Cancer Institute.

Frank von Hippel—Chairman, Federation of American Scientists; Senior Research Physicist, Princeton University Center for Energy and Environmental Studies.

Michael H. Walsh—Vice President for International Operations and Subsidiaries, Cummins Engine Company, Inc.: Trustee, Stanford University.

Melissa Wells—United Nations Development Program, Geneva; former United States Ambassador and U.S. Representative to the United Nations Economic and Social Council.

George M. Woodwell—Director, Ecosystems Center, Woods Hole Marine Biological Laboratory; former President, Ecological Society of America; Member, National Academy of Sciences Committee on International Environmental Programs.

The Institute also has a highly qualified executive staff. The President of the Institute is Gus Speth, former Chairman of the President's Council on Environmental Quality and now a professor of law at Georgetown University in Washington, D.C. Mr. Speth has dealt extensively with national and international resource issues, and chaired the Carter Administration's cabinet-level Task Force on Global Resources and Environment. Mr. Speth holds graduate degrees in law from Yale University and economics from Oxford University.

The Institute's Vice President and Research Director is Jessica Tuchman Mathews, a scientist with extensive experience with public policy issues. Dr. Mathews has served as Director of the Office of Global Issues on the Senior Staff of the National Security Council and is currently a member of the Washington Post editorial board. She holds a doctorate in biochemistry and biophysics from the California Institute of Technology.

The Institute's Vice President for Operations and Development is Wallace Bowman, currently the Executive Director of the Commission on Natural Resources of the National Academy of Sciences. Prior to accepting his position with the Academy, Mr. Bowman was for eleven years Chief of the Environment and Natural Resources Division of the Congressional Research Service of the Library of Congress. He holds a graduate degree from Yale University in natural resources conservation.

VI. PROJECT SELECTION AND EXECUTION

At this point, the description of program priorities for a new Institute should be suggestive, not definitive. The choice of studies to be pursued, particularly the early projects, will be crucial to the Institute's success. They should therefore be decided upon only after a searching inquiry to identify the best ideas, and after discussions with a variety of scientists and policy experts.

Nevertheless, a good deal can be said now about: (a) the focus of the Institute's efforts; (b) the range of topics from which studies might be selected; (c) the criteria by which potential projects would be judged; (d) the means of assuring factual and analytic soundness in Institute work; and (e) ways in which problems might be addressed. These topics are discussed below, together with an illustrative description of a possible study—the Preservation of Genetic Diversity.

A. The focus: Both national and international

The Institute will be concerned with large-scale issues of planetary importance, and not with issues of local or even national significance only. For example, it might address the issue of acid rain or the buildup of carbon dioxide in the atmosphere but would not address federal air quality standards for carbon monoxide.

And it would be concerned first, but not exclusively, with the effects of public and private U.S. actions with the respect to those problems. The United States can contribute to global problems (CO_2 emissions) and to solutions (leadership in controlling use of chlorofluorocarbons). Some seemingly domestic U.S. problems have global implications (loss of agricultural soils and lands; SO_x emissions), in part because of the scale of U.S. activities. The policies of the U.S. Government and large private concerns can effect both directly and indirectly such global problems as deforestation, species loss, desertification, and water pollution and supply. As a United States-based organization, the Institute would speak with authority regarding U.S. activities and policies.

Nevertheless, the problems transcend U.S. borders and necessarily involve many other countries. It is important for the Institute's work to have credibility abroad, for the Institute's studies to be realistic and informed about the perspective and constraints of other involved countries, and for the Institute to allocate a significant portion of its resources to being effective abroad. Each of these objectives will be pursued. All will be furthered by the commitment to involve foreign scientists and others fully in the Institute's networks and studies and on the Institute's staff.

B. Global resource and environmental problems of priority concern[3]

1. Loss of cropland and agricultural resources.—Global food production will have to increase by almost 50 percent in the next twenty years simply to keep pace with population growth. With little good land that can be brought into production, a great premium attaches to protecting existing agricultural resources, particularly land and water. Yet, present trends are ominous. Deterioration of soils is occurring rapidly in many regions of the world.

Desertification claims an estimated 6 million hectares a year, an area about the size of Maine. In the United States, 225 million acres have been classified as undergoing "severe desertification" due to overgrazing, erosion, groundwater mining and poor irrigation drainage that can result in salt buildup. Erosion, the loss of topsoil can be rebuilt only with great difficulty and time, has reached critical levels in parts of the United States and elsewhere, due to overuse, monocrop agriculture, deforestation and other causes.

Loss of good cropland to urban encroachment is another problem affecting the United States and many other countries. In the United States about 3 million acres of potential agricultural lands are converted to other uses each year. Florida has lost an estimated 200,000 acres of citrus lands, about a fourth of the total.

Other pressures on agricultural resources include loss of water due to overuse of groundwaters, wasteful irrigation practices, pollution and competition from urban and industrial users; extinction of wild or local crop strains needed by plant breeders for improving cultivated varieties; and the impacts of rising fuel costs on energy-intensive agriculture.

The needs are clear: to understand better these problems and their relationships to other issues; to assess what options and improvements could have the most beneficial results and in what time frames; and to discover solutions that are synergistic and help solve, rather than create, other problems and that are robust enough to survive being parcelled out in the real world. Certainly, these are issues where a major policy studies commitment is needed.

2. CO_2 buildup and the greenhouse effect.—The CO_2 content of the atmosphere has increased 15 percent over the last century, with most of the growth in recent decades. The cause is directly attributable to human activities, and current estimates suggest that CO_2 could double its preindustrial level before the middle of the next century.

The effect of the increased burden of CO_2 in the atmosphere is a global warning, now believed detectable by complex analyses of temperature records and perhaps as a decrease in the amount of sea ice in the Antarctic. Future increases in CO_2 could produce further temperature changes globally, a shift in climatic zones, changes in agricultural potentials and productivity and within decades to a century or more, a rise in sea level of 15–20 feet. Such changes would obviously have serious economic, social and political impacts.

These threats could be mitigated by appropriate actions. Beyond the need to continue basic research, there is a need for sophisticated policy analysis focusing on both national and international dimensions. Better understanding is needed of real global and regional energy demands, of possible ways to meet

[3] See also the discussion of genetic diversity at pages 190–192 and of fresh water resources at page 190.

those demands without the risks of a large CO_2 buildup, of means to promote reforestation and enhance the resilience of agricultural and social systems to climate change, and of practical ways to improve international cooperation. Physical milestones might be identified, before they occur, when particular policy responses would be called for.

3. Global deforestation.—The world's tropical forests are disappearing at disturbing rates as growing numbers of people seek land, wood and raw materials. Forest losses are already causing numerous social, economic and ecological problems—intensified seasonal flooding, water shortages in dry seasons, accelerated erosion of agricultural lands siltation of rivers and coastal waters and the disappearance of plant and animal species at rates without precedent.

The policy questions presented by this problem and its relationship to economic development and other problems are exceedingly complex. Perhaps more than any other of the major global concerns, the United States has taken steps in stimulating an international attack on deforestation. Independent studies in this field can not only explore new issues but can also assess the progress that has been made and perhaps learn valuable lessons from it.

4. Global pollution and toxic chemical problems.—The past 50 years of industrialization can easily be characterized as the "chemical revolution." In the United States alone the annual production of synthetic organic chemicals has risen from 150,000 pounds in the late 1920s to more than 300 billion pounds at present. While humanity has benefitted greatly from these advances, poor practices inadequate disposal and indiscriminate use are the source of a growing international concern. The overuse of pesticides, for example, has produced resistant pests while at the same time killing off natural predators. The careless handling of toxic substances today pose dangers to plant, animal and human life in virtually all areas of the world. Many persistent toxic chemicals such as DDT and PCB's are now being detected throughout the biosphere, even in what appear to be remote mid-ocean, antarctic, or arctic stations.

The assessment and management of chemicals poses a major global challenge. The United States has, for the most part, adequate domestic legislation to address these problems within its borders. Many of the less developed countries have entered, or will soon enter, a period of rapid industrialization. Systems of balanced and far-sighted environmental management are needed for these historic changes. There is a need for wider sharing and standardization of information among many countries concerning hazardous substances and treatment and disposal processes. The Institute, freed from the charge of seeking economic advantage often associated with governments, could document the extent of chemical flows and releases, assess and predict effects, evaluate economic implications and identify national and international courses of action.

5. Global energy future.—Although there is movement toward consensus in the U.S. regarding likely domestic energy needs two or three decades hence, the question of global energy needs over this period has not been sufficiently studied. Given the stakes, studies of global and regional energy futures are of critical importance.

Global constraints of several types are very likely incompatible with the realization of a future in which global energy use per capita reaches the current level of use in the United States or even Europe. Fortunately, there appears to be room for dramatic reductions, relative to current U.S. or European practice, in the level of energy use required to provide a desirable standard of living, and these opportunities are by no means confined to the developed nations. One important challenge is to identify ways to assist the developing world in anticipating emerging energy-efficient approaches, so that they do not waste resources imitating current energy-wasteful systems. A second challenge is to find ways to make the impact of international energy policy on issues of equity within developing countries at least neutral, if not positive, in fostering the needs of the rural and urban poor.

Another vital class of global energy issues relate to food-fuel coupling. Decisions to promote liquid fuels based on corn in the United States or sugar cane in Brazil have a secondary impact on the price and availability of food; this coupling would appear to deserve a very thoughtful exploration. Yet another set of issues concern the establishment of effective international institutions and arrangements to manage the nuclear fuel cycle.

6. Ocean resource utilization and degradation.—The promise of fish and other biotic resources, minerals and energy resources is triggering tremendous pressure on the oceans, a global commons which covers 71 percent of the earth's

surface. Yet, international programs adequate to assure a sustainable yield of these resources are not available. Similarly, because no one is held accountable for the quality of the ocean ecosystem, it is under increasing stress from pollutants washed from land or dumped off coastal areas and from the destruction of highly productive coastal wetlands and reef areas. As nations become more strict in the protection of their land, air and internal waters, the use of the oceans as an "over the hill" dumping ground grows. Policy studies are needed in this area to define better the problems and the relationships among them, to identify relevant political and economic considerations, and to assess alternative strategies for oceans management and conservation.

7. *Possible studies of the capacity of governments and others to respond.*—Over the past decade a huge expansion has occurred in the monitoring of the global atmosphere, ocean, and land resources, both by surface measurements and by satellite. A major role has been played by the United States. Yet priorities regarding what to measure, and at what level of effort, have not adequately reflected the policy concerns. Moreover, information that is available from new technologies has not been sufficiently used in policy analysis. The Institute might investigate these issues and make recommendations for generating credible statistical information on global conditions and trends in the resource and environmental area and for linking the policy and the global environmental measuring communities.

The Institute might also look at where, how, and why successes have been realized in addressing global-scale resource and environmental issues. By bringing forward positive results, this study could be an important political stimulus as well as a source of practical information.

Historical analysis should prove similarly enlightening. Patterns of large-scale human alteration of the natural environment in the past can be studied for useful lessons, as can long-term historical trends.

Another Institute initiative might examine the uses and misuses of integrated global models and explore their relationship to improving U.S. foresight and anticipatory capability. A different approach to traditional modeling would be an exercise aimed at examining the year 2000 and later years under the assumption that we and others make a major international effort to address the global problems described here. Thusfar, major modeling efforts have tended to focus on the "base case"—the future assuming that major policies and trends stay much as they are today. A more positive vision of an achievable, workable future could be technically and politically useful.

C. Project selection criteria

The difference between a focused and valuable new institution and just another set of studies will lie, first of all, in the amount of thought spent on choosing among candidate studies, on creative shaping of the policy issues to be addressed and in developing a long-range direction for the Institute. Therefore one of the staff's first tasks will be the development of a set of criteria for consideration and approval by the Board of Directors. These criteria will be used to evaluate suggested studies and to help assure the most productive use of the Institute's limited resources.

The criteria are likely to include:

Inherent Significance—is the issue now or likely to become of major global or regional significance? It need not now be widely recognized as such. Is any damage that may be occurring to environment or resources irreversible? Is there a need for an "early warning"?

Policy Interest—can alternative policy responses be identified? Do the needed solutions raise issues of policy, either public or private? Are political, economic, and social considerations essential?

Intellectual Ripeness—can the problem be usefully studied at this time? Are adequate data available or can they be generated? If the latter, can they be produced in the appropriate time, and at what cost? Is there a reason for a new study (e.g., new data, widespread confusion about facts, unrecognized problems)? What can a new study add that does not duplicate others?

Policy Ripeness—who could do what with the results? Are there legislative decisions or international conferences (or conflicts) pending? Are there foreseeable decisions that will be forced by continuing trends? What is the level of possible U.S. involvement, either in the problem or its solution? Is the problem tractable?

Follow-on Activities—can steps be taken to inject the results into a policy process? Are there other countries or regions that might wish to adopt the study

model for their use (parallel country studies)? Are there natural follow-on studies? How can key audiences best be reached?

Fit with Other Institute Activities—does the project complement interests and expertise of existing staff and fellows? Does the type of study (primarily technical vs. political, new work vs. update, domestic vs. international) balance other current projects?

One additional consideration should influence the choice of the first several projects. The Institute's goal is eventually to build an international audience and reputation. To do this it must first establish its credibility as a national organization, capable of making important contributions to the U.S. policy process. But it must avoid becoming seen as another organization concerned solely with U.S. (or developed nation) interests. The early projects should attempt to meet both these goals.

D. Quality assurance, peer review and scientific advice

The Institute will insist on technical and analytic soundness in its studies. It will rely on established methods of peer review, on formal and informal scientific advisory mechanisms, and on other means to further this objective.

In one approach that will be frequently used, a review committee will be established at the outset of a new project. Its members will include experts working in the field under investigation as well as others from outside the particular field but with relevant disciplinary backgrounds. Members will be solicited from academia, business, non-governmental organizations, and elsewhere. The committees will include, rather than exclude, those companies or groups with direct interests at stake, since they frequently will know the most about aspects of a problem. The Institute will look for individuals who are smart and fair but not necessarily neutral on a controversial subject.

A review committee will meet as soon as possible to examine all aspects of the proposed study outline and will be asked to identify milestones during the course of the study when subsequent meetings or reviews of the drafts by mail should take place. Project staff will present their progress at those meetings.

Should the review committee be deeply divided over the adequacy of a study or negative in its opinions, the Institute may solicit the views of additional reviewers, direct a redo of all or part of a project, or take other action. Though the review committee's views will be given heavy weight, the members will not be asked to approve or endorse or take responsibility for the actual report or its conclusions. This arrangement should assure that the project staff has the benefit of the full range of expert views, and that the Institute's reports are accurate and scholarly, while avoiding the endless quarreling over language and watering down of recommendations that inevitably overtakes an expert committee of widely varying viewpoints.

To make plain the importance the Institute attaches to their work, members of review committees will be paid a fee comparable to a government or industry consulting fee, in addition to expenses.

The scientists participating on these review committees, the numerous scientists on the Institute's board of directors, and other leading scientists who will assist and advise the Institute will form the Institute's science and advisory capability. In addition to the natural and social scientists on the Institute's board and the many outstanding scientists associated with the three affiliated spoke groups, the following leading individuals have also expressed interest in assisting and advising the Institute in appropriate circumstances:

Gilbert F. White—Institute of Behavioral Science, University of Colorado; President, Scientific Committee on Problems of the Environment.

Ellis B. Cowling—Associated Dean for Research, School of Forest Resources, North Carolina State University; Member of the National Academy of Sciences.

F. Herbert Bormann—Professor of Forest Ecology, Yale School of Forestry and Environmental Studies; Member of the National Academy of Sciences.

Edward Goldberg—Professor of Chemistry, Scripps Institution of Oceanography, University of California at San Diego; Member of the National Academy of Sciences.

Thomas F. Malone—Director, Holcomb Research Institute, Butler University; Foreign Secretary, National Academy of Sciences.

Lynton K. Caldwell—Professor of Political Science, Indiana University.

Robert W. Kates—Professor, School of Geography and Center for Technology, Environment and Development, Clark University; Member of the National Academy of Sciences.

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E. Modes of approach

The organization, content and modes of analysis will vary too much from subject to subject and circumstance to circumstance to specify rigidly in advance. However, in addition to the general characteristics of good policy analysis described in Sections II and IV of this proposal, the Institute will make use of the following approaches:

In many cases, it should be possible, and would be desirable, to summarize concisely in one section what is factually known about a given problem, in other words, to attempt to delineate clearly where consensus ends and controversy begins.

In evaluating policy options, in addition to characteristics that are commonly analyzed—e.g., cost, use of physical resources—the Institute will give equal attention to other more subjective but equally important characteristics, including political feasibility, likelihood of implementation, and value questions (who benefits from a particular policy, and who pays? What values are advanced by the policy?).

A common failing of policy studies is to make recommendations as though everything outside the scope of the study did not exist. On the other hand, in the natural world, everything is ultimately connected to everything else, and a study that attempted to cover all associated factors would become impossibly diffuse. Particular care will be given in defining Institute studies to avoiding both tunnel vision and a sacrifice of depth for breadth.

Where possible, studies will look at the effectiveness and impacts of alternative national approaches to environment and resource management. Much has been learned, for example, about the preservation of farmland by comparing different approaches the 50 states have taken. On the international level, an opportunity exists for nations to learn from others' successes and failures.

Parallel country studies can be a useful approach. For example, there is a need for more study of U.S. water resource policy. It is frequently said, with some justification, that water may be to the 1990's what energy was to the 1970's. Water policy may therefore be an attractive candidate for a broad-gauged Institute project. But many other countries and regions face similar water problems. The Institute might try to stimulate studies abroad parallel to its analysis of the U.S. situation. Data can be shared, analyses critiqued, resources pooled (e.g., the costs of creating a computer model useful to both parties might be divided).

In the policy arena timeliness and presentation are vital. A single idea, or series of ideas contributed as a debate develops, can be more valuable than a comprehensive 2-year study which arrives a year late. Institute staff and fellows will be encouraged to stay alert to these opportunities and to contribute shorter items with modest leadtimes.

Unlike scholarly research publications, policy studies do not have an automatic, captive audience. Every effort must therefore be made to make them readable, attractive and accessible to the non-expert. Special attention will be given to organization, layout, the use of good graphics and color.

Length is another consideration. Policymakers who will use these studies and journalists who will publicize them seldom have the time to read a lengthy document. The traditional executive summary, in which every key finding is crammed into a few dense pages, is not a good answer. The Institute will strive to produce readable, illustrated (with charts, graphs) summaries of manageable length, perhaps separately bound from the main report. In the case of major projects this may take the shape of a separate volume suitable for commercial sale.

F. Outline of a sample project: The preservation of genetic diversity

Harvard Magazine recently asked seven prominent members of the Harvard faculty what each felt was the most important problem facing the nation or the world. E. O. Wilson, Frank Baird Professor of Science, answered this way:

"Permit me to rephrase the question as follows: What event likely to occur in the 1980s will our descendants most regret, even those living a thousand years from now? My opinion is not conventional, although I wish it were. The worst thing that can happen—will happen—is not energy depletion, economic collapse, limited nuclear war, or conquest by a totalitarian government. As terrible as these catastrophes would be for us, they can be repaired within a few generations. The one process ongoing in the 1980s that will take millions of years to correct is the loss of genetic and species diversity by the destruction of natural habitats. This is the folly our descendants are least likely to forgive us."

Wilson is not alone in this view. Scientists, especially those familiar with the speed of current destruction of tropical rain forests, speak regularly of approaching "ecological catastrophe." Yet this concern is poorly reflected in the concerns and policies of governments, in part because of inadequate understanding of the dimensions of the problem and the alternatives for addressing it.

If present trends continue, perhaps as many as 20 percent of the plant, animal and microbial species now living could be extinct by the year 2000. Only a few of the likely costs of such a loss are currently identifiable, and even these few are difficult to overstate. Species and gene resources capable of providing immeasurable benefits—food, shelter, drugs, energy, resistance to disease and pests, adaptability to climate and environmental change—will be lost, usually without ever having been identified. Ironically, the loss is occurring just as the revolutionary techniques of genetic engineering make it easier to utilize these genetic resources for the benefit of mankind.

Because of the scope of this project, a likely first step would be a review by the Institute staff including identification of key individuals working in the field, summary of ongoing national and international efforts to address the problem, and review of present recommendations for action.

An international study group might then be convened, which, based on discussion papers prepared by the staff, would attempt to identify the policy-related research needs, the greatest opportunities for practical action, the trends most in need of documentation, and from these and other considerations, order priorities among the many possible ways to approach the topic.

Among the questions the study group would address would be the following:

Is preservation of genetic diversity best achieved through protection of individual species or of habitats? If the latter, do we know enough to be able to define critical habitats? How much (2 percent, 20 percent?) of a given habitat—for example, a tropical rain forest—must be set aside in order to preserve gene resources?

What sort of human uses are compatible with species preservation? What can be learned from areas that have been intensively developed yet still support flourishing ecosystems? How effective are parks, biosphere reserves, sanctuary farms and other suggested mechanisms? Can any of these be made compatible with the urgent human needs that must be met in developing countries?

Can or should particular areas be identified as most urgently in need of protection? Should these be defined by habitat—rain forest, grassland, wetlands, etc.—or through species type—animal, plant (terrestrial and aquatic), microbial? If these cannot be accurately specified now, what research, exploration, and cataloging is necessary?

It has been postulated that a certain level of species loss is an early warning of a collapsing resource base: "Outrageous as it may seem, it has been historically true that a nation which cannot protect its biological diversity is unable to protect the standard of living of its people. Much as the first symptoms of an ecosystem under stress are endangered species and their ensuing loss, so, too, the first symptoms of a nation overreaching its biological resource base are endangered species and a reduction of biological diversity." (Lovejoy, 1981.) Is there scientific support for this contention? Can it be translated into a useful component of national and international development strategies?

What practical steps are justified on the basis of existing information? Germplasm and seed banks for plant and microbial species are technically simple and appear to cost a fraction of their value. What financial or other types of help can be provided to nations (e.g., Indonesia, Brazil) that are already attempting to stem genetic losses?

How best can public and governmental consciousness be raised? Is it through better documentation of the direct value of natural products to human societies in the production of drugs, chemical and industrial products (oils, waxes, dyes, resins), energy, as well as food? Exploration of the need for genetic diversity in the maintenance of crop resistance to disease and pests? Better public knowledge of the benefits hidden in as yet unexplored species? Recently, a species of perennial corn was discovered, nearly wiped out, and, almost by accident, saved, on a single hillside in Mexico. If this perennial strain could be successfully bred as a food crop, it could expand acreage where corn can be grown (it tolerates wet, humid conditions), save untold costs in the plowing and seeding necessary for annual crops, save great amounts in pesticide costs (it is resistant to major corn fungal and viral diseases) and transform erosion losses.

These are just a few of many possible topics. The study group's goal would be to define and order the most important approaches. In reaching its decisions to group would consider any scheduled conferences or approaching decision-making milestones within the United States, the U.N. system or regional groups.

After the study group had prepared a study outline, a scientific review committee would be chosen and convened, and the project launched.

Senator MATHIAS. Thank you, Mr. Speth.

One of the statements that you made raises an interesting issue, and that is that the U.S. Government should improve its modeling capability. I think that is what you said. But that raises the issue of whether the Government should do it or whether we should rely on the private sector to do it.

We had an opportunity to make that decision a couple of years ago—well, more than a couple, I suspect—when Vice President Rockefeller offered to turn over to the Federal Government his Commission on National Priorities, with all of its staff and all of its files and an ongoing project. We estimated that it would cost about $1 million a year to operate.

Now, this was not strictly global modeling, but it is in the same vein of inquiry. That decision was brought to the Senate Appropriations Committee late one afternoon, when there was a rump session winding up over an appropriations bill. Some of the senior members of the committee—I do not think we had a quorum, but we were still doing business—heard out Senator Mansfield and Senator Scott, who proposed that we take this over.

And these senior Members said, well, that is just an effort by Nelson to get the Federal Government to finance his next Presidential campaign. So they turned it down, which I think was a very short-sighted decision. But there was the other reason, I suspect, in their minds also: Should the Government be in this business?

What do each of you think about that?

Ambassador RICHARDSON. My view, Mr. Chairman, is that the Government is in the business, and the question is how well it carries out its role. The global report on the year 2000 seems to me significant in a number of dimensions, but most of all in its identification of the deficiencies in the existing capacity of any institution or combination of institutions in the United States to make the necessary projections.

It pointed in considerable detail to these deficiencies. The more recent report by the Office of Technology Assessment reemphasizes these findings and makes recommendations also for how to do a better job. Well, the job being done is mostly a job being done, and necessarily being done, by Government agencies to which data are reported and will have to be reported. The problem, then, is to try to assure that the data are received in more or less compatible forms, and then to create the links among the collecting agencies which in turn can contribute to building a coherent picture.

It is hard, indeed I think it is impossible, to see how any private sector agency or entity could do that. The question of what kind of models are then built utilizing these data is of course a different question, and what groups or entities draw policy judgments from them is still a third kind of question.

But it would seem to me on the face of it that the Government should at least be responsible for some models and perhaps help to support

the existence and the use of others. As to the policy conclusions, it seems to me that any entity established to improve the collection, coordination and analysis of data should be separate from the use of these data for policy decisionmaking purposes.

The planning, in other words, should be separated from the data, for the reasons you briefly touched on and because the planning needs to be carried out not only by Government but by the private sector.

Another way of putting the point I was making earlier in that connection is, the better the planning in the private sector the less likely the need for Government intervention and the better able the private sector will be itself to deal in the long leadtime terms that it all too seldom does.

We have all heard criticisms of the lag of American productivity that derives from the quarter to quarter, year to year, remaining term as CEO syndrome of American business. It would be a mistake, I think, to look at the development of the kind of capability we are talking about here as a resource to be used only or even primarily for the Government.

But to the extent that that is true, there does need to be maintained, as I suggest, a functional separation between the compilation and analysis of data and its application to the formulation of policy.

Senator MATHIAS. Would you agree with that, Mr. Speth?

Mr. SPETH. I do. I think there are certain things that are absolutely essential for Government to do, and in fact they won't get done if Government does not do them. As the head of what will be a very large private institution in this area, I can tell you very frankly that we are not going to be able to engage in data gathering, in collation of that information, in being sure that the various information series about different indices and problems are compatible and accurate; and we need in the Federal Government a capability for strong data and monitoring of conditions and trends and analysis.

While that has to be supplemented, particularly at the analytical levels, with a strong capability in the private sector and nongovernmental organizations of many types, there is no substitute for a strong governmental capability, and for an investment of a relatively small amount, in the millions, today, I think we will save the country billions later on.

Senator MATHIAS. In the OTA report which Dr. Gibbons discussed this morning, he has made some recommendations for congressional oversight—establishment of a single congressional mechanism for continued oversight of population issues, a review of criteria for determining which countries receive population assistance and channels through which the assistance is funneled, review of the U.S. priorities and restrictions in addressing global population issues, such as prohibition on aid to China, consideration of ways to accelerate the pace of self-sufficiency in the LDC's and to encourage greater participation of the private sector in LDC's, to address the fact of product liability suits, shortened patent life, and FDA's export provisions on drugs, which may be inhibiting the development and manufacturing and marketing of contraceptives and other medical products.

Would you have any comments on those recommendations?

Mr. SPETH. Not in any depth, Mr. Chairman. I think in general things of that nature are certainly going to have to be done, and the

level of effort that the Congress gives to these issues and the level of coordination that it gives to these issues will probably bear the same kind—or could bear the same kind of improvement and coordination that the executive branch needs to engage in.

Ambassador RICHARDSON. That sounds right to me, Mr. Chairman. Since I believe that there should be created a Government agency carrying out the role that we have just been talking about, it would be appropriate that there be a Government committee that occupied the same relationship to that agency that the authorizing committees do for all Government agencies.

It would not follow that the committee exercising that kind of oversight into the role and effectiveness of what I will call the Government data compilation agency would have the power to correct all the things that were thought to be inadequate from a programmatic standpoint, for example, the pace of the FDA's processing of new drug applications for the control of pregnancy.

That timing obviously would involve considerations belonging, so far as Congress is concerned, to whatever committee had jurisdiction over the FDA, and there would be no way of ousting that kind of responsibility.

Mr. SPETH. Mr. Chairman, if I might add one thing in answer to your question about governmental activities in this area. When we did the Global 2000 report we knew we were making a first step, perhaps only a small first step, in relation to what needed to be done.

My own view is that that effort needs to be redone with more sophistication and with learning from the mistakes that were made in it, and then we also need to look beyond this base case analysis of what happens if policies do not change, and factor into a model, if you will, a better model, the results of what can happen if indeed we do respond in an affirmative way to the problems that were identified in the base case analysis.

Those types of studies, while they involve the nongovernmental sector extensively and indeed in some aspects of them can be done outside the Government, they would, I think they will, require the kinds of resources that the Government can bring to bear on the problem. I would like to see that governmental activity return periodically to those issues that we addressed in Global 2000.

Senator MATHIAS. You mentioned that Global 2000 perhaps should be redone and updated. Secretary Watt at one time had proposed that that be done. In fact, I think he invited Russell Train to participate in the process.

Do you know how far they have gotten on that?

Mr. SPETH. No, Mr. Chairman, I do not. I have complete ignorance about that development.

Senator MATHIAS. We will make some independent inquiries.

Mr. SPETH. When I say it was our intention to continue the effort——

Senator MATHIAS. By "redone," you do not mean to tear it down and start over, but you mean to update, correct, fine-tune and refine it, do you not?

Mr. SPETH. Yes. Thank you.

Ambassador RICHARDSON. I would add, Mr. Chairman, that I think there ought to be created the capacity to make such projections on an annually continuing basis. Once you set up the mechanism and you have

the data flowing in from the various sources within the Government that are responsible for collecting this information, it ought to be possible in principle, I should think, to produce an annually updated version incorporating not only new data, but any refinements in the meanwhile in the manner in which the model itself is constructed.

Senator MATHIAS. That would certainly be my personal feeling.

Gentlemen, we thank you both very much for being here. We appreciate your testimony.

Ambassador RICHARDSON. It was a pleasure, Mr. Chairman.

Mr. SPETH. Thank you, Senator.

Senator MATHIAS. Our final witness this morning is Mr. Alan Hill, Chairman of the Council on Environmental Quality. Mr. Hill, as you are coming to the witness table, Governor Romero and I have to have a brief word in the back room.

We will be right back.

[Brief recess.]

Senator MATHIAS. Mr. Hill, we are very sorry for this delay.

Mr. HILL. I am sorry to have been late, Mr. Chairman.

Senator MATHIAS. We are happy to have gotten together despite our mutual schedules.

Would you proceed?

STATEMENT OF A. ALAN HILL, CHAIRMAN, COUNCIL ON ENVIRONMENTAL QUALITY

Mr. HILL. Mr. Chairman, my name is Alan Hill and I am Chairman of the President's Council on Environmental Quality.

I have a full statement that I have provided, and I ask that it be made a part of the record.

Senator MATHIAS. Without objection, your full statement will appear in the record.

Mr. HILL. With that let me briefly hit some highlights, and then we can go to questions.

As you know, one of the major functions of the Council, per statute, is to gather information on conditions and trends in the quality of the environment, both current and prospective.

In looking back over the history of forecasting, as early as the administration of President Theodore Roosevelt have efforts been made to institutionalize, inventory and preserve our natural resources. Since that time various administrations have experimented with methods and mechanisms to collect and use reliable data.

All of these efforts have suffered from some problems. The deficiencies are basically of timeliness, economy, sophistication, and in some cases the education of the intended users.

There are many misconceptions about the capability of computer-based models to accurately predict future conditions. Policymakers must remember that models cannot predict the future because the future is uncertain and the model is incapable of instantaneous response to unpredicted variables. Instead, models answer "what if" questions developed by the modeler. Modeling should not be regarded as an end in and of itself.

Mathematical equations should not be the driving wheels of government, determining its directions. Those responsibilities reside with

the elected and appointed officials who occupy policymaking positions. Policymakers must determine governmental objectives, and models merely serve as tools to show the impact of a proposed decision. It must be remembered that models and the forecasts that come from them are only as good as the information on which they are based.

Certainly an indispensable requirement for reliable modeling of any kind is timely, accurate, verified information. Many sources collect and assemble global data, and quite often they do not generate it. Most such data are received from foreign agencies and individuals. Interestingly, the Soviet Union recently announced that its statistical reports could not be relied on for accuracy. There is also a tendency for errors introduced into a system to enlarge with time and distance, thus affecting both the validity and usefulness of a projection subject to such background deficiencies.

If credence is to be placed in the results of a modeling effort, the quality of data must be substantially improved. Obtaining better conclusions is not to be found in more sophisticated hardware, centralized analytic or modeling offices, or a managerial willingness to use the product of the modeling effort. It is very simply extremely good data, good analytical equations, and good assumptions provided by those individuals who are fully acquainted with the objectives of the organization and the realities of the situation being examined. Further, the limitations of the modeling system itself must be understood and accepted.

With my prejudices now on the record, I would like to review the activities of CEQ in this regard.

The Global 2000 Report to the President, published in 1980, is of course the most comprehensive and visible of the Government's predictive analysis of global issues. The Council and the Department of State were the joint leaders of the project, which also involved 11 other Federal agencies, and at this point, I would like to congratulate Chairman Charles Warren for initiating the Global 2000 project, and Chairman Gus Speth who saw the project through to completion. Not only was it the first comprehensive report of its kind by the U.S. Government, but it was the first report on a global scale prepared by any government.

Global 2000 is an important first step to address a number of global issues which have potential impact on U.S. national interests, including national security. The process illustrated the shortcomings in the United States national capability to gather data and to forecast future trends.

This past spring I asked the study director of Global 2000 for his views on the problems in developing global models. This report points out that Global 2000 was not intended to be a definitive study of the future but merely to provide a foundation for additional work. We are using Global 2000 as part of the foundation on which to base this administration's review. I have formed an interagency working group on global issues. The working group provides the administration through the Cabinet Council process, with the collective thinking of senior officials able to take policy level responsibility to recommend appropriate Government action on global environmental issues of national concern.

We hope to suggest mechanisms to improve the quality of the Government's information base, assess, and recommend improvements in the ability of Government to forecast future trends, and provide an optimal basis for long-term policy decisions.

As an initial project, the working group has developed a set of global environmental principles to guide policy development. A copy of those principles is attached to my testimony.

Second, we are completing preparation of an inventory of all existing U.S. international activities, multilateral and bilateral, pertaining to the environment and natural resources. At the present time there is no comprehensive listing such as this available.

Our next major effort will review existing programs and make recommendations as to how we can improve our forecasting capabilities, recognizing the shortcomings of the process. As pointed out by the Global 2000 Study Director, Global 2000 shows that executive agencies of the U.S. Government are not now capable of presenting the President with internally consistent projections of world trends and population resources and the environment for the next two decades.

We are also involved with a number of international organizations. These activities that are particularly relevant to our global interests are those that relate to environmental data and statistics, and to briefly run through the list, I have cited our involvements with the Organization for Economic Cooperation and Development [OECD], which published its State of the Environment Report in 1979 and will publish another in the not too distant future; the United Nations Environment Program in which we participate in the Coordinating Committee on the Ozone Layer, its International Register of Potentially Toxic Chemicals, and the Global Environmental Modeling System.

We are also involved with the United Nations Statistical Office in a project that will be valuable in improving our understanding of environmental conditions in less developed countries.

Finally, though the Economic Commission for Europe [ECE], we are working on standardizing methods for compiling and reporting certain types of environmental data. Our experience has shown that common definitions and reporting formats are extremely important in establishing large global data sets, and therefore we continue to work with ECE in its standardizing activities.

The administration's objective is to correct the shortcomings of the past which have caused needless loss in the United States and world productivity. We want to develop and put into action accurate methods which will allow us to hypothesize about future global conditions. We want to use this information to analyze our global policies and help guide decisions on Government actions that affect global circumstances.

Thank you very much.

[Mr. Hill's prepared statement follows:]

PREPARED STATEMENT OF A. ALAN HILL

Good Morning. My name is A. Alan Hill. I am Chairman of the President's Council on Environmental Quality (CEQ). CEQ was established by the National Environmental Policy Act to advise the President on environmental issues. Among our other functions is the responsibility to gather information on "con-

ditions and trends in the quality of the environment both current and prospective. . . ." Because of CEQ's long-standing interest in this area it is a pleasure to have the opportunity to summarize the Council's activities relative to developing global trends in population, natural resources and environment.

The Federal Government has been grappling with the problem of how to improve its data gathering and forecasting capabilities to predict and solve future problems for some time. Theodore Roosevelt attempted to institutionalize a body for the inventory and preservation of natural resources in 1908. Various administrations since have experimented with mechanisms to collect and use reliable data to make long range, accurate forecasts of resource needs. These attempts have often suffered from deficiencies of timeliness, economy, sophistication, or, in some cases, the education of the intended users.

THOUGHTS ON MODELING

There are many misconceptions about the capability of computer-based models to accurately predict future conditions. Policymakers must remember that models cannot predict the future because the future is uncertain and the model is incapable of instantaneous response to unpredicted variables. Instead, models can answer "what if" questions developed by the modeler. Consequently, it is doubtful whether global projections can ever be made in more than general terms because of the ever-changing social, economic, political, physical world in which we must live.

The global models that presently exist have one thing in common. They are all projections of trend lines developed by computer manipulated model data bases. In using such projections, it must be remembered that the models are not objective or goal oriented. Modeling should not be regarded as an end in and of itself.

Mathematical equations should not be driving the wheels of government and determining its directions. Those responsibilities reside with the elected and appointed officials who occupy their positions specifically to determine goals and develop programs for reaching them. Policymakers must determine governmental objectives and models merely serve as tools to show the impact of a proposed decision.

It must also be remembered that models and the forecasts that come from them are only as good as the information on which they are based. Certainly an indispensable requirement for reliable modeling of any kind is timely, accurate, verified, factual information. The information must be translatable into computer language, and accurate, pertinent assumptions must be prepared as part of the process. Unfortunately, the reliability of data collected by U.S. agencies from overseas sources is often suspect. Although the embassies, the CIA, the Departments of Defense, Commerce, Agriculture, and others collect and assemble data, they do not generate it. Most such data are received from foreign agencies and individuals. The data may or may not be reliable. In some cases, such as China, which is estimated to contain over 25 percent of the world population, the numbers reported by the government represent only guesses. The third world countries vary widely in the reliability of their reported data. The Soviet Union recently announced that its statistical reports could not be relied upon for accuracy. The question for modelers then becomes one of whether to utilize inaccurate data, misleading data, or no data.

There is also a tendency for errors introduced into a system to enlarge with time and distance, thus affecting both the validity and usefulness of a projection subject to such background deficiencies. A small error in data will, when projected over 20 or 30 years, become a gross error and may be of such magnitude as to destroy not only the reliability of the projections but the credibility of the system as well.

If credence is to be placed in the results of a modeling effort, the quality of data must be substantially improved. Obtaining better conclusions is not to be found in more sophisticated hardware, centralized analytical and modeling offices, or a managerial willingness to use the product of the modeling effort. It is very simply extremely good data, good analytical equations, and good assumptions provided by those individuals who are fully acquainted with the objectives of the organization and the realities of the situation being examined. Further, the limitations of the modeling system itself must be understood and accepted.

My purpose in making the above observations is to record my views as to the inherent problems of relying absolutely on and accepting as fact trend lines established by models. This is especially true with respect to global issues since

one must remember that the data base on which the models build is of questionable reliability. However this is not to say that global forecasting has no place in policy development as long as its weaknesses are well recognized. With my prejudices now on the record I would like to review the activities of CEQ in this regard.

THE GOBAL 2000 REPORT

The Global 2000 Report to the President, published in 1980 is, of course, the most comprehensive and visible of the government's predictive analyses of global issues. The Council and the Department of State were the joint leaders of that project, which also involved 11 other Federal agencies. Not only was it the first comprehensive report of its kind by the U.S. Government, but it was the first report on a global scale to be prepared by any government.

Global 2000 is an important first step to address a number of global issues which have potential impact on U.S. national interests, including national security. The process illustrated the shortcomings in the U.S. national capability to gather data and to forecast future trends.

It is critical to recognize the inherent and self-admitted drawbacks in relying without question on the information in Global 2000. This past spring I asked the study director of Global 2000 for his views on the problems in developing global models. I have a copy of that report with me and request that it be made a part of the hearing record. This report points out that Global 2000 was not intended to be a definitive study of the future but merely to provide a foundation for additional work. We are using Global 2000 as part of the foundation on which to base this Administration's review.

GLOBAL ISSUES WORKING GROUP

In order to provide the President with sound policy coordination among the agencies, I have formed an interagency working group on global issues. The Global Issues Work Group provides the Administration, through the Cabinet Council process, with the collective thinking of senior officials able to take policy level responsibility to recommend appropriate government action on global environmental issues of national concern.

The working group has begun working on the formidable tasks in its charge. As we progress, we hope to suggest mechanisms to improve the quality of the government's information base; assess and recommend improvements in the ability of the government to forecast future trends; and provide an optimal basis for long-term policy decisions.

As an initial project, the working group has developed a set of Global Environmental Principles to guide policy development. A copy of those principles is attached.

The working group is completing preparation of an inventory of all existing U.S. international activities, multilateral and bilateral, pertaining to the environment and natural resources, in order to assess whether the United States is maximizing its resources to best accomplish its international goals. At the present time, there is no comprehensive listing available. We want to assure ourselves that we are neither duplicating efforts nor concentrating too many of our resources in inappropriate arenas. Those issues of most significant dimension must be accorded priority consideration.

Our next major effort will review existing programs and make recommendations as to how we can improve our forecasting capabilities recognizing the shortcomings in the process. The importance of this effort is reinforced by The Global 2000 study director's report which stated that Global 2000 "shows that the executive agencies of the U.S. Government are not now capable of presenting the President with internally consistent projections of world trends in population, resources and the environment for the next two decades."

In addition to the activities of the Global Issues Work Group, CEQ, EPA, and other U.S. agencies concerned with the environment participate in several environmental programs with a number of international organizations. Activities that are particularly relevant to our global interests are those that relate to environmental data and statistics. The international organizations provide a means by which we can receive uniform sets of data and statistics dealing with environmental matters in foreign countries. Some examples are listed below.

Organization for Economic Cooperation and Development (OECD).—OECD has a State of the Environment project for the purpose of assembling, organizing, interpreting, and publishing environmental information for the OECD countries

(Western Europe, the United States, Canada, Japan, and Australia). OECD published a State of the Environment Report in 1979 and is in the process of gathering data for a new report. Subjects covered are quality of air, quality of continental and marine waters, forests, land use, solid wastes, wildlife, and noise. The project may be expected to provide the best information available on the state of the environment in the Western industrialized countries.

United Nations Environment Program (UNEP).—UNEP's program activities include a variety of global issues and UNEP's Coordinating Committee on the Ozone Layer, its International Register of Potentially Toxic Chemicals, and its Global Environmental Monitoring System are resources to which we shall be looking for a variety of data.

United Nations Statistical Office (UNSO).—The UNSO in New York, at the request of and with financial support from UNEP, has undertaken a program to improve the quality of environmental statistics with five objectives: (1) to prepare a series of guidelines papers on various aspects of environmental data; (2) to prepare a survey of country practicts in the field of environmental statistics; (3) to convene a series of regional workshops and pilot studies in order to test materials and familiarize regional groups with the program; (4) to survey data gaps; and (5) to prepare a framework for organizing and developing environmental statistics. The UNSO project will be valuable in improving our understanding of environment conditions in the less developed countries.

Economic Commission for Europe (ECE).—The ECE Office of Environmental Statistics has made considerable progress in standardizing methods for compiling and reporting certain types of environmental data. It has developed an international system of classification of land use that now is being applied in the OECD State of the Environment project. It has developed and is reviewing formats for reporting on water use, and it will soon be working on schemes for reporting water quality. Our experience has shown that common definitions and reporting formats are extremely important in establishing large global data sets, and therefore we continue to work with ECE in its standardizing activities.

CONCLUSION

It is clear that in the next several decades, we will face increasing stresses in resources and environment on a global scale. As the President stated in the Cancun Meeting on Cooperation and Development, the United States, as a technological leader, important producer of food, and a leading user of energy, has an important stake in these issues. Our economy, the welfare of our people, and our national security are involved.

Too many times in the past, the United States and other nations of the world have been caught in international crises because we lacked information on important changing global conditions, and we did not have the capability to foresee a problem until it was too late to act. In other cases we have made decisions on global policy without considering their total impact.

The Administration's objective is to correct these shortcomings of the past which have caused needless loss in U.S. and world productivity. We want to develop and put into action accurate methods which will allow us to hypothesize about future global conditions. We want to use this information to analyze our global policies and help guide decisions on government actions that affect global circumstances.

ENVIRONMENTAL PRINCIPLES

A healthy environment is fundamental to the well-being of mankind.

Economic growth and social progress are necessary conditions for effective implementation of policies which will protect the global environment and promote wise use of the earth's natural resource base.

Environmental policy should be based on the interests of present and future generations. The most successful policies are those which promote liberty and individual rights, as well as protection of the physical environment.

Nations should pursue economic development in furtherance of the security and well-being of their citizens in a manner which is sensitive to environmental concerns. Due respect should be given to different approaches which various nations may adopt to integrate environmental considerations into development strategies based on their particular national values and priorities.

Careful stewardship of the earth's natural resources can contribute significantly to sound economic development. Individual ownership of property, free and well-developed markets in products and capital are powerful incentives for

resource conservation. These institutions best promote the use of renewable resources and the development of substitutes for non-renewable resources, ensuring continued resource availability and environmental quality.

When environmental problems extend beyond the boundaries of any one nation, all affected nations should participate in investigating the nature of the problem, understanding its implications, and developing cost-effective responses.

Governments, like individuals, should act so as to minimize environmental degradation. Decisions on environmental policies and programs should take into account the concerns of those closest to the problems and most directly affected.

Increased scientific understanding of environmental problems, and improved methods of forecasting environmental conditions, are needed to address environmental issues in an effective and efficient manner. Ultimately, resolution of environmental problems which are global in nature will be determined by the quality and credibility of our scientific and technical knowledge as well as by the degree of cooperation among nations including the effective involvement of private sector institutions.

Senator MATHIAS. Thank you, Mr. Hill.

I particularly welcome the portion of your statement in which you say that Global 2000 is an important first step in—I want to get the exact words and quote them—

Is an important first step to address a number of global issues which have potential impact on U.S. national interests, including national security.

Mr. HILL. Yes.

Senator MATHIAS. I agree with that. That has not been the universal view, as you are, I am sure, well aware, but I think it is the correct view, and I find it very hopeful that you are taking steps to implement the findings of Global 2000 and to upgrade them. I think it is also realistic that you call it a first step. It is not the ultimate in knowledge. It is a first groping for knowledge on a global scale.

I think you have already done this to some extent, but even if it is repetitive, perhaps you could tell us why you think this kind of foresight capability is important for the U.S. Government, because this, of course, as you well know, is the kind of thing that we get criticized for. My good friend, the Senator from Wisconsin, awards the "Golden Fleece" for projects that go out to garner information about subjects that seem esoteric to the general public.

Why is it important?

Mr. HILL. Mr. Chairman, I tried to state some concerns about modeling. Modeling is not the be-all and end-all. What we are trying to do, and maybe being a little less charitable, is to develop factual base on which we can make a better educated guess as to the impact of a proposed action, try to anticipate some of these things.

I had a conversation not long ago, to give you a very practical example, regarding projections on U.S. food production and the potential for export. Questions were raised by the transportation industry, because we cannot build a ship or take a ship off the shelf. We have to have export facilities, we have to have carriers and so forth. So the need to have information to project what will our projected production be, what will the world demand be at various periods of time, we have to have this information both for the Government and for the private sector.

Senator MATHIAS. What about the impact of failures on this process? For example, I can recall making speeches myself back in the late 1960's in which I was predicting that by 1980—or I think maybe I said between 1980 and 1985, the United States would be depending on foreign sources for 50 percent of its oil. Well, as a matter of fact, it

was before or around 1975 that we became 50-percent dependent on foreign sources for oil.

Then, of course, the projections were, well, it will be going up to 75 or 80 percent someday, but in fact, we now see some decrease in dependence on foreign sources.

So what about the fact that the trends do not always lead us to the conclusions that a casual glance would indicate that they are leading us to?

Mr. HILL. I think that goes to the point I touch on very briefly about the timeliness, the availability of information. Can we make it more timely? That is one of the difficulties that was encountered during the preparation of Global 2000.

The Barney study, which you have, lists some of Dr. Barney and the study team's frustrations in dealing with the system as it existed at that time. I think he cites one. It is a vignette, admittedly, but very significant point. The group of modelers who were called together to work on this from the participating agencies, many of them had never met each other before. So that was the condition at that point. We hope to improve at least that level of coordination.

Senator MATHIAS. Is that one of the purposes of the Interagency Global Issues Working Group?

Mr. HILL. Yes.

Senator MATHIAS. I would like to have Dr. Barney's study be made a part of the record at this point.

[The information referred to follows:]

[DRAFT]

IMPROVING THE GOVERNMENT'S CAPACITY TO ANALYZE AND PREDICT CONDITIONS AND TRENDS OF GLOBAL POPULATION, RESOURCES, AND ENVIRONMENT[1]

(By Gerald O. Barney)

EXECUTIVE SUMMARY

The purpose of the Global 2000 study was not to provide the definitive study of the future, but rather to establish a foundation for on-going foresight analysis within the Federal Government. The study identified the best models, data and professional staff within the Government, and through the study process, established a foundation for the Government's foresight analysis.

The findings of the Global 2000 study are not particularly startling. Assuming a continuation of present policies, rapid technological advance, continued operation of the market system, and no wars or major economic disruptions, the study found that the population growth would continue well into the twenty-first century; that there would be much further economic growth; that the gap between the richest and the poorest would widen; that no quick, easy solutions to the world's energy problems are in sight; that more food will be produced, but at higher cost; that in a few parts of the world, per capita food consumption may decline; that by the turn of the century several environmental problems—especially soil erosion, loss of genetic resources and certain atmospheric problems—are likely to be more severe than today; and that in some parts of the world, populations are putting sufficient pressure on the land to erode and reduce the carrying capacity of the land. The study concludes that the situation is by no means hopeless, but that the problems cannot be solved by any one nation alone and that concerted and timely action is needed.

Population, resource and environmental problems are becoming issues of national security for virtually every nation. The time has passed when any

[1] © 1982, Gerald O. Barney and Associates, Inc., Research on World Problems, 1730 North Lynn Street, Suite 400, Arlington, Va. 22209, March 24, 1982.

nation can think of its future security and welfare independent of developments affecting population, resources and the environment. The time has also passed when any nation can think of its future in these regards independent of what is happening in the rest of the world.

The issues of population, resources and environment are becoming so interrelated and complex that computers are needed to understand the implications of alternative policies and programs. Unfortunately, careful study of the best global models now available in the U.S. Government shows that the Executive Agencies of the U.S. Government are not now capable of presenting the President with internally consistent projections of world trends in population, resources and the environment for the next two decades.

The extent of the problems with the Government's models is reflected in an experience early in the development of the Global 2000 Report. When the senior professional persons responsible for the long-term global analysis in each of the fourteen participating agencies came together for a meeting, not one had ever met any of the others. In general it was found that the models and data employed by the various agencies are shot full of internal contradictions and inconsistencies, the overall consequence of which is that the projections and policy analyses made by the agencies almost certainly underestimate the seriousness of the long-term problems facing this nation and the world. In short, the analytical foundations of the Government's policy analysis and foresight are seriously flawed.

One basic problem is that the Government's institutional structures were designed before the need for computer-assisted analysis of complex issues. As they have evolved, the Government's agencies now have a hidden layer of decision makers—computer programmers and modelers. These decision makers are, by and large, very skilled professionals, but they are often working in institutional circumstances which prevent them taking into account all the factors they know should be taken into account. Furthermore, the assumptions that they make have a profound influence on the range of policy options considered by senior government officials, and their assumptions are not well documented, are not understood by senior government officials, and are not available for peer review and comment.

To improve the situation, increased coordination of models development and documentation is needed by the Executive Office of the President. The models and analysis, however, should remain within the individual agencies, close to the constituencies that understand the issues involved. The nation does not need an office of global planning in the White House basement.

Changes are also needed in the Congress. Committees responsible for foresight would be helpful, as would strengthening of the foresight responsibilities of the Office of Technology Assessment, the Congressional Research Service, and the General Accounting Office.

Private sector participation is also needed. To compete effectively in world markets, the private sector needs a highly professional Government, capable of formulating wise, long-term policies. Short of this, countries like Japan will continue to have competitive advantage. Private sector participation in the formulation, improvement and maintenance of policy should be encouraged.

OVERVIEW AND BACKGROUND

Overall statement of work

The contractor will assist the Council on Environmental Quality and other cooperating agencies to plan, coordinate, and develop steps to improve the Government's presently inadequate capability to analyse and predict conditions and trends of global population, resources, and environment. The contractor is to analyze and recommend remedies for deficiencies in predicted models, the data basis on which they operate, and institutions that use them.

The Global 2000 Report to the President prepared by the Council on Environmental Quality and the Department of State, in cooperation with eleven other participating agencies documents a number of inadequacies in the Government's analytical and foresight capabilities. The analysis and recommendations in this report are based on the Global 2000 Study and other information.

For the purpose of this report, some background information on the Global 2000 study is needed, information that goes beyond what was published in the study.

The structure of the Global 2000 Report was influenced significantly by the origin of the study directive. The study directive was not a White House initia-

tive. The idea originated with Dr. Donald King at the State Department. King had long wanted to see the United States undertake a study of world problems and in the spring of 1977 he learned that the White House had agreed that President Carter would send an environmental message to the Congress. King promptly prepared two paragraphs calling for a study of world problems and discussed his idea with Dr. Lee Talbot and Mr. George Bennsky, the CEQ staff members drafting the environmental message. They liked King's idea and inserted his two paragraphs in the draft message. The draft went to the White House; no one crossed out King's paragraphs. The message was typed in final form, and on May 23, 1977, President Carter signed it.

The directive drafted by King had only two operational sentences:

"* * * I am directing the Council on Environmental Quality and the Department of State . . . and other appropriate agencies, to make a one year study of probable changes in the world's population, natural resources, and environment through the end of the century. This study will serve as the foundation for a longer-term planning."

I began work on the study in early September, and to my surprise, found that there would be only 6 months to conduct the study because the "one year" had begun the minute President Carter signed the message, and the Government Printing Office would require 3 months to print the report. I also discovered that it would be necessary to raise the money to conduct the study since King's directive provided no budget. Finally I discovered that there was no staff and very little office space. Ultimately, the study required three years for its completion, and cost approximately one million dollars, including the contributed efforts of the participating agencies. But we began the study thinking that only 6 months would be available to complete the analysis.

With this tight time schedule in mind, I interpreted the purpose of the study—to establish a foundation for longer-term planning—to mean that the study process, rather than the report itself should serve as the foundation for longer-term planning. Clearly, a report based on a 6-month study of such major problems could not serve as a very effective foundation and for this reason, it was never my intent that the Global 2000 Report be considered a definitive study of the future. Since a suitable foundation for longer-term analysis and foresight must consist of trained personnel, high quality data, and excellent models, I intended to prepare the best study possible within the available time, and to use the study process as an opportunity to assemble the best data and models and the most skilled professional personnel within the United States Government thereby creating a functioning team and an on-going foundation for foresight and analysis of long-term issues and policy options. For reasons explained below it was not possible to explain these purposes of the report very clearly in the Summary Volume of the Report, and as a result, the purpose of the study have often been misunderstood.

A number of assumptions in the Global 2000 study have also been misunderstood. The assumption most often misunderstood is that of "no change of policy."

The idea for this assumption originated with Mr. Charles Warren, a veteran of many years in the California legislature and then Chairman of the Council on Environmental Quality. During the first week of the study, Mr. Warren remarked that he had seen many studies brought to the legislature in California, virtually all of which assumed that the legislature would act in some manner, and as a result of the assumed legislative action the study came to a happy conclusion. Mr. Warren remarked that in his experience, the legislators looked at the happy ending of the report, and ignored the fact that the happy ending was premised on action by the legislature. As a result, nothing happened. To avoid this difficulty, Mr. Warren directed that the Global 2000 analysis should be conducted assuming no changes in public policy worldwide. If the future implied by a general continuation of present policies was less than ideal, Mr. Warren argued, it should be up to policy officials throughout the world to decide what changes would be necessary to lead to a brighter future.

One of the reasons there is misunderstanding about the assumption of continuation of policies is that the first four words of the major findings and conclusions in volume 1 read as follows: "If present trends continue . . ." The Global 2000 study assumed a general continuation of public policies worldwide, not a continuation of present trends. The study found that if public policies remain generally unchanged, many trends can be expected to change over the next two decades. The statement "If present trends continue . . ." was that of an editor at CEQ, and

although I objected to the statement as incorrect, it was not possible to have it corrected.

A second important assumption concerns technology. The technological assumptions were left entirely to the professionals in the Government's agencies, and in general the assumptions were that there would be rapid development of new technologies and rapid adoption of the new technologies. A few examples follow:

All the population projections assumed that almost all countries that do not already do so will make family planning technologies and services available to an appreciable portion of the population during the 1975–2000 period, and countries with family planning programs now in operation will extend coverage, particularly in rural areas. This meant, for example, that in the census projections for Bangladesh (in the medium-growth case), fertility rates were exogeneously projected to decline 40 percent over the 1975–2000 period.

Almost all the GNP projections for the LDC's assumed that the productivity of capital in the LDC's will increase significantly over the 1975–85 period. This meant, for example, that in the "other South Asia" LDC group, a given investment could be thought of as producing 60 percent more incremental GNP in 1985 than in 1977 (in constant dollars).

All the food projections assumed that the widespread deployment of fertilizer and other yield-augmenting inputs (together with other factors) will lead to further increased yields comparable to the increases experienced over the past two decades (the period of the Green Revolution). This meant, for example, that annual LDC grain production was projected to increase 125 percent over the 1975–2000 period (in the medium case).

All the energy projections assumed the widespread deployment of light-water nuclear electric power plants. This meant, for example, that electrical generation from nuclear and hydro-power sources was projected to increase about 200 percent over the 1975–90 period (in the medium case).

All the energy-residual projections (i.e. projections of residuals such as pollutants or waste heat from energy conversion processes) assumed implicitly that major public and private investment will be made in pollution abatement technologies so that by 1985 all energy facilities in all countries will have met or have been retrofitted to meet 1978 U.S. new source performance standards for various emissions.

The study assumed that the market mechanism will continue to be effective throughout the period of the study, limiting demand and providing further incentive for supplies whenever supply constraints are encountered.

The study assumed no political conflicts or economic disruptions. In effect, the study assumed that there would be no revolution in Iran, no takeover, in Afghanistan, no assassination of President Sadat, and no difficulty in Central America. These developments add complications and difficulties beyond those discussed in the report.

The study produced four types of results: (1) the trend projections: (2) an historic analysis of the government's previous long-term studies: (3) the assembly of a team of professionals, data and models: and (4) an analysis of the ways in which the Government's capacity for foresight and long-term analysis could be strengthened.

The trend projections.—The agencies' projections contained very few surprises. For the most part, the findings had been published previously in other studies. Population growth is projected to slow slightly, but with no possibility of an end to population growth until well into the twenty-first century. Much further economic growth is anticipated both in an absolute sense and in a per capita sense, but the gap between the richest and the poorest is expected to widen. No quick, easy solutions are anticipated for the world's energy problems. Per capita food consumption on the world average is expected to increase, but production costs and consumer prices are expected to rise. While forests in the industrialized countries are relatively stable, substantial forest losses are expected in the developing countries. Loss of productive soil over the next decades is expected to be a serious problem in many parts of the world. None of these basic findings are particularly new or surprising.

The historic perspective.—This analysis found that there is a 70-year history of long-term studies and analyses by the U.S. Government. The historic analysis found that many useful recommendations from earlier studies went unheeded. Details of the historic analysis can be found in Appendix A of the second volume of the Report.

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The foundation.—In the course of the study, the professional personnel responsible for the long-term global analyses and each of the participating agencies were identified and brought together as a working team. These professionals, together with the best data and models that they could provide, constitute the foundation for longer-term planning and analysis assembled by the study. The participating individuals are identified in the preface and acknowledgements to volume 2, see especially pages x and xi. The models and data are described in chapters 14–23 of volume 2 and in volume 3.

The evaluation.—In addition to asking the agencies for projections for the study, I also asked them for information on how the projections were made. Based on this information, I and a few of my staff analyzed the assumptions in these models. The description of the models is provided in volume 3 of the study and the evaluation of the models is provided in chapters 14 to 23 of volume 2. The basic finding is that while the government has significant analytical capabilities supported by an enormous amount of data, there is inadequate coordination of the analysis among the agencies. As a result, there are a large number of internal contradictions among the agencies' models and assumptions.

In the course of preparing the summary volume (volume 1) of the Global 2000 Report, there was much concern by various Government officials that candid discussion of inconsistencies and contradictions in the Government's long-term analytical models would undermine the credibility of the study's projections. As a result, the discussion of the analytical problems had to be kept to a minimum in the summary volume. The analytical problems are discussed to some degree, but a fuller and more candid discussion would have been useful. It is accurate to portray the study as reconnaissance both of the future and of our ability to look ahead. In short, the study should be seen in the light of its original intent as the first step in an on-going process to improve and strengthen the government's foresight capabilities.

The Global 2000 Report contains no policy recommendations. The reason is simply that we wanted to avoid a formal interagency clearance process involving all 14 of the participating agencies. As a result, the Report is strictly a professional document, reporting the analysis of the best professionals available within the Government.

After the Global 2000 study was released in July of 1980, President Carter established a task force to prepare recommendations. The recommendations were prepared hastily by a group of people who had nothing to do with the preparation of the Report. None of the professional people who worked on the Global 2000 study were permitted to have any part in the preparation of these recommendations. The recommendations were published under the title, "Global Future. Time to Act." The preparation of the recommendations became highly political, and ultimately, three of the five members of the task force refused to sign the Report.

Task 1: Documentation of problems with global models

The Contractor will prepare a brief summary of technical problems associated with use of integrated global models and the major sectoral models on global population, resources and environment. This summary will include, but not be limited to, the models described in volumes II and III of the Global 2000 Report to the President and other major models used by the Federal Government and international organizations.

In considering the problems of using integrated global models or sectoral models on global population, resources, and environment, it is important to recognize that it is impossible to avoid using models. Everyone uses models in making decisions and taking actions. For the most part, the models used are mental models, i.e., mental images of how the economy works, or how a business functions, etc. The consequences of alternative policies and actions are weighed and evaluated in our mental models as a basis for making decisions. Formal analytical models in computers are used in the same way and are merely explicit representations of mental models.

Mental models and computer models each have relative advantages. Mental models are exceedingly flexible, able to deal with macro-issues one moment, and micro-issues the next. Formal computer models have less flexibility, but impose discipline (in requiring assumptions to be made explicit) and provide logical consistency (by tracing accurately the analytical implications of the assumptions and data). In addition, computer models are able to cope with vastly more data and interactions than can the unaided human mind. Thus, computer models provide a highly useful extension of human mental capabilities, and are essentially an explicit representation of someone's mental model.

Perhaps the single most serious problem associated with computer-based global (and not-global) models is that as a society we are still in the process of learning how to use computer-based models. Computers themselves are still relatively new; virtually no one over the age of 45 had the opportunity to grow up with computers as an integral part of their educational experience. Computer-based models are even more recent, and the nation's intellectual leadership is still in the process of learning how to use this new tool for extending the capabilities of the human mind. Some of the problems of using computer-based models are illustrated by the difficulties encountered in using the government's models to conduct the Global 2000 study. The Global 2000 analysis was initiated with an eight-page memorandum listing all of the projections which would be needed for the study. This memorandum was circulated to the participating agencies along with an indication of which of the projections the agencies would be responsible for. The agencies were all visited and the most professional personnel, the best models, most current and complete data were located. The professionals were then asked to produce a first draft within 6 weeks.

At the time the first drafts were due, a weekend-long retreat was held at the Belmont House in Maryland. The primary discovery at that meeting was that none of the professionals directly responsible for the long-term global analysis in each of the participating agencies had ever met. They were total strangers. The energy expert had never met the water experts. The food expert had never met the population expert, etc. As a result, our first priority was to make acquaintance and begin the process of seeing that the assumptions being used by the various departments were as internally consistent as we could make them.

At that time we also began the analysis of the content of the models. We knew in advance that the Government does not have what is normally thought of as a "global model," i.e. a single model containing separate interacting sectors dealing with population, resources and environment. We discovered, however, the Government does have a "global model." In the Government's global model, the population sector is located in a computer at the Bureau of the Census. The energy sector is located in a different computer at the Department of Energy. The food sector is located in a different computer at the Department of Agriculture, etc.

In analyzing these sectoral models, we discovered that they are in fact an interacting set of global sectoral models that collectively constitute the Government's global model. Each of the sectors needs information from the others. The energy sector for example, needs economic and demographic and water projections for input. The population projections require information on the social and economic conditions that influence fertility and mortality rates as inputs. The food model needs information on fertilizer and energy prices, on water availability, economic conditions, and demographic trends.

In analyzing these models, we found that information was flowing from one sectoral model to another even though the persons responsible for the models did not know each other. The medium of communications was the Government Printing Office. Studies were prepared with one sector of the Government's global model, sent off to the Government Printing Office, printed, purchased by another Government agency, and the results entered into another sector of the Government's global model. In the process of conducting the Global 2000 study, we introduced all of the Government's professionals to each other, expediting interaction among the models by a factor of perhaps as much as a million simply by by-passing the normal mode of communication through the Government Printing Office.

In looking at the institutional assumptions under which the sectors of the Government's global model were developed, it is apparent that these models were developed assuming that meaningful projections could be made in an individual sector without dynamic interaction with developments in another sector. This means for example, that meaningful agricultural projections might be made without following on a year-to-year basis developments in the energy sector. The net effect of such assumption is that virtually every one of the resource-oriented agencies is assuming that their particular sector of the economy will have access to all the land, energy, water, and investment capital that they think their particular sector will need, without any means (at present) even to total these assumed availabilities to see that they are within the maximum that is available on the planet. Almost certainly, the energy and agriculture projections, for example, are assuming that both of these sectors will be able to use some of the same land, water, and investment capital for very different purposes. More specifics on the problems and difficulties with the Government's global model can be found in

chapters 14 to 23 of the second volume of the Global 2000 Report and in volume III of the Report.

Such problems of double counting are only one of a large number of contradictions and inconsistencies that abound in the assumptions and structure of the Government's global model. In addition, some sectors are simply missing (e.g., water, forests, grassland and many aspect of the environment) and some sectors are particularly weak (e.g. non-fuel minerals, and energy). All of the sectors need to be better interlinked, and the models need to become dynamic rather than static.

While there are many problems with the Government's global model, the more highly integrated global models are not without problems of their own. The first computer-based global models (the World 2 and World 3 models) used in developing World Dynamics and The Limits to Growth) presented problems in being highly aggregate. While useful for some purposes, the highly aggregated structure of these models precludes their application to many policy issues.

Following the publication of the original global models, a new generation of more detailed models has been developed. These more detailed models a'so face difficulties in that their data requirements are large, and as a result, the models are difficult for any one institution to maintain. These models quickly become dated without maintenance. Another problem is that it has not been possible to make the analyses performed with global models directly relevant to national decision-makers, and there are no global decision-makers. Sovereign nations are the most aggregate level at which effective decisions are made. Nonetheless, a number of institutions are beginning to employ global models. The United Nations has its World Economic Model. The International Labor Organization has acquired and improved a world model that was developed originally in Argentina. The Department of the Environment in London has developed a global model for the U.K. Government. Here in the United States, the Joint Chiefs of Staff, the Department of Agriculture and the Department of the Interior have acquired the World Intergrated Model.

Task 2: Summary of problems with global data sets

The Contractor will prepare a brief summary of the major problems with respect to existing global data sets on population, resources, and environment, particularly with respect to their use in forecasting. This summary will include, but not be limited to, the data sets used in preparing the Global 2000 Report to the President and data used in conjunction with major models used by the Federal Government and international organizations.

There are both real and imaginary problems associated with global data sets. One real problem is that there are some areas in which the data is simply not available. Information on grazing land, for example, is virtually unavailable. Demographic data is very inaccurate for some parts of the world. Some of these data gaps are being filled by improved statistical reporting, and it may be possible to correct some of the gaps at relatively low cost with remote sensing data from satellites.

Another very real problem is political bias in data. The staffs of United Nations agencies are not permitted to question data provided by individual countries, and even a cursory examination of some of the U.N. data suggests that the information is quite inaccurate in some case. Allowing U.N. staff members to question the accuracy of data submitted, could, in the long run, make substantial improvements in the accuracy and quality of the data available.

An imaginary problem with data relates to the issue of how the data is used. "Data problems" have been and will continue to be a convenient excuse for postponing difficult decisions. It is always easy to say that more data is needed, before a difficult decision can be made. In the course of many years of observation, I have seen a number of costly data collection systems producing data that was probably far more detailed and frequent than needed for its application. While more data are needed, it would be well to define precisely the accuracy, frequency and geographic detail required before major expenditures on data are approved. The data requirements for global modeling need to be determined interactively. The best data that is available, even if it is based only on the informed judgment of experienced observers, needs to be used openly and without apology when nothing better is available. Once such applications are made, sensitivity tests are needed to determine the degree to which the data in question have a significant influence on the model results and policy decisions that might be made from the model results. If results and decisions are found to be sensitive to specific uncertain data, then further data collection is justified.

No discussion of the problems with data would be complete without mention of the practice of choosing certain data sets to obtain the "right" answers. The

Bureau of the Census' high series of population projections, for example, has been used on more than one occasion to justify projects that would not have been justified by the use of the medium series projections. In some cases discussed in Chapters 14–23 of volume 2 of the Global 2000 Report, it appears that particular agencies have, in the past, developed specific models and used specific data with the specific objective in mind of justifying pre-conceived policies and programs. Such practices need to be avoided.

Task 3: Summary of institutional problems

The Contractor will identify the major institutional factors that have interfered with and reduced the effective development and use of models and data sets for predicting and forecasting on global population, resources, and environment. This might include factors such as lack of demand and use on the part of policy analysts; insufficient training of staff; lack of financial support; lack of coordination among the agencies; lack of congressional and (or) legislative mandate; and other factors that the Contractor might identify from its own experiment.

The primary institutional problem is simply that governmental institutions were designed at a time when the major problem facing societies were far more separable than they are today.

The world problems of concern today are not easily separable geographically or sectorally. The time has passed when the United States can manage its energy (or population, or agriculture, . . .) problems independently of what is happening elsewhere in the world. Compounding the complications of this geographic coupling is a growing amount of inter-sectoral coupling world-wide. The point put simply is that the world does not have an energy problem. The world does not have a population problem either. Or a food problem. Or a water problem. What the world has is an energy-population-food-water . . . problem. There is no possibility of understanding the world energy (or demographic, or food, or water . . .) trends independent of what is happening in many other sectors. These sectors have all become highly interdependent.

While the time has passed when United States and world problems can be meaningfully considered to be independent geographically and sectorally, governmental institutions are still structured as if most issues were sectorally and geographically separable. In the Executive Branch, for example, it is far easier to cope with a problem that is perceived to be a farm problem than it is with one that is perceived to be a farm-population-water-energy . . . problem. Similarly in the Congress, there are a variety of committees to focus on individually discrete and separable problems, but as Congressman John Dingle remarked in hearings recently, no Committee in either the House or Senate has jurisdiction sufficiently broad to hold hearings on the range of interrelated topics covered by the Global 2000 Report. (It is interesting that the entire Italian Senate set aside a full day for hearings on the full range of topics covered by the Global 2000 Report.)

Another fundamental institutional problem, is that the Government's processes of decision making were designed in large part before the availability of computers and the Government's decision making processes have not evolved to effectively use or manage computers as an aid in decision-making and policy formulation. Unobserved and unplanned, the government has evolved a hidden layer of decision makers—the professional computer programmers and model builders—who have a profound influence on the conduct of government and on policy formation, but whose work goes virtually beyond scrutiny, evaluation and review. It is these hidden decision makers who manipulate enormous quantities of data through computer models and present departmental secretaries, White House officials and the Congress with evaluations of policy options. The assumptions these hidden decision makers build into policy analysis are written in FORTRAN, not English, and are beyond examination. The department secretaries have no knowledge of many of the assumptions underlying the policy analysis done for them. I know because I have spent far more time trying to understand the Government's long-term global models than any departmental secretary could, and I cannot understand many of the assumptions.

The Global 2000 Report concluded, "to put it . . . simply, the analysis (of the Government's global model) shows that the Executive agencies of the U.S. Government are not capable of presenting the President with internally consistent projections of world trends and population, resources, and the environment for the next two decades." The fundamental reason for this inability is that no one is monitoring the work of the new, hidden layer of decision makers. They are, for the most part, very competent people, but they work under tight deadlines, with inadequate budgets and staff, and with almost no incentives to document their assumptions and analyses. Also, since these professionals work in institutional settings that emphasize strictly sectoral approaches to policy analysis,

it is not surprising that the intersectoral linkages, so vital in understanding the problems now facing the United States and the world, are largely undeveloped.

The complexity of issues today demands that computers be used in policy analysis. It will be impossible, however, to obtain the full benefit of computers in policy analysis unless careful attention is given to the process through which computers are applied. A central consideration in this process is documentation and peer review of the assumptions and models being made by the computer professionals who have gradually become major decision makers in Government.

Finally, I would say that one fundamental problem facing the U.S. Government is the tendency to rely on outside experts rather than building up a strong group of professionals within the Government. It has even reached the point where outside experts are brought in to design the contracts that will be given to outside experts. It is no wonder that the United States is constantly surprised by world events that seem to have been well anticipated by the Japanese, when one considers that the U.S. Government does not have a model of the world economy. I found many people in Government using world economic projections whose origin they did not even know. (Many of these projections derived from the United Nation's or from the World Bank's economic models, both of which contain assumptions that are largely unknown to many Government officials using these projections.) It is equally unsatisfactory that the U.S. Government officials rely on proprietary models of the U.S. economy, models whose structure and assumptions cannot be evaluated.

Task 4: Recommendations

The Contractor will prepare a set of recommendations as to what actions the Government should take to improve the Government's presently inadequate capability to analyze and predict conditions and trends of global population, resources, and environment. The Contractor will consider, as a minimum, recommendations for solutions to the problems identified under Tasks I, II and III.

My first recommendation is that under no circumstances should there be an office of global (or even national) planning established in the White House basement. While the United States definitely needs to apply computers to the analysis of problems in population, resources and environment, an isolated office of global or national planning would likely develop a perfect analytical solution to the world's problems that simply would not work in the real world.

My second recommendation is that we recognize that the problems of population, resources and environment are becoming issues of national security and deserve increased attention. The future national security of this nation depends on access to orderly world energy and grain markets. A healthy farm sector depends upon future energy, water, capital, soil, and transport conditions. Future availability of trained personnel will be influenced by the maintenance of a strong educational system and also by the flows of migrants into this country. These complex, inter-related issues will require the extensive use of computers for analysis in many different parts of government, the private sector and other institutions.

To analyze these complex, interrelated issues, the Executive Branch will continue to need long-term global models, while these models will be more realistic and useful if kept in the agencies, close to the constituencies that know the subject matter, the coordination among these models needs to be improved. Improved coordination might be accomplished by a small office somewhere within the Executive Office of the President. The responsibility of this office would be to follow closely the assumptions being built into the agencies' models as well as the maintenance and documentation of these models. The office would also be responsible for examining the relevance and quality of the data being employed by the agencies.

The coordination office might also manage a periodic up-date of the agencies' long-term projections and monitor the agencies' plans for revision and replacement of their models. Most of the models now in existence are not capable of the types of interlinkage that should be achieved among the agencies, and as the agencies plan for modification or replacement of their models, someone should insist that the capabilities for inter-linkage through magnetic tapes or through direct inter-linkage between computers are provided. The coordination office should also be a source of documentation on all of the agencies policy models, making this material available for peer review.

It is also recommended that within the Executive Branch there be provision for more extensive funding of long-term global analyses in universities and research institutions outside of the Government. No one office or group of Government agencies can claim perfect understanding of future trends, and the nation will be well served by a diversity of foresight activities. In addition to computer models, normative approaches should be encouraged.

The Congress also needs to give attention to the ways in which it deals with foresight. At present, foresight responsibilities are scattered through a variety of committees. The Congress may also want to think about establishing foresight committees in the House and Senate, or perhaps a joint foresight committee. Mr. Dingle's observation that the Congress does not have a committee with jurisdiction appropriate to hearings on the entire Global 2000 Report, is very telling.

The three organizations serving the Congress—the Office of Technology Assessment, the General Accounting Office, and the Congressional Research Service—all provide some foresight work for the Congress. The Congress might benefit from a careful examination of the foresight work done in these three support agencies, with an eye toward the foresight needs that the Congress will need five or ten years from now. If some coordinated planning could be undertaken now, these institutions might be much better prepared to serve the Congress in a few years.

It will also be important to involve the private sector. The nation is already experiencing intense competition from industry in Japan and elsewhere, and as time goes on even more competition can be expected. If the nation's industries are to compete effectively, it will be essential that the Government agencies become at least adept at foresight and long-term policy formulation as the Government of Japan. The private sector must, therefore, be encouraged to take an interest in the development of long-term policy tools within the Government, and to actively, participate in and monitor the development of these tools.

Senator MATHIAS. And let me just pause right here and say that having observed Washington bureaucracy for 20 years now, I think you had better get another name. If you make an acronym out of that, it is IGIWG, and that will run you out of town alone.

So rename it promptly. [General laughter.]

IGIWG.

We were having terrible luck for appropriations for the National Science Foundation some years ago, and I discovered that one of the reasons was because the scientists were so honest and so unsophisticated that they were telling us the exact names for these various scientific experiments that they wanted funding, and of course, you could make all sorts of fun out of them, and if you looked at them with a public relations eye, you could say the same thing in ways that could not be twisted. I am not suggesting that you can make fun out of IGIWG, but I think it is so important that I do not want you to run risks with it.

How do you fund it? Are the members just working members of agencies?

Mr. HILL. These are generally, the members are at the Assistant Secretary level, and of course, they do not charge CEQ for their time. As a project is being developed, each of the agencies has chipped in the manpower or whatever resources is necessary. For instance, the inventory effort on our international involvements was staffed principally by the Department of State, as you would assume, and ably backed up by the EPA and others. So the participation comes in that way.

Senator MATHIAS. What is your agenda for this year? What kinds of things do you have in hand for the rest of this year?

Mr. HILL. At our next meeting we will be taking up the Barney Study, which then leads us to the entire question of forecasting, which I see we have gone through a familiarization process. We have developed a set of principles. The group has gotten to know each other. We are completing the inventory process for our involvement. So each one of the participants has become I think more aware of what his or her agency is actually doing at the present time, and it is quite an extensive list of involvements.

So the next step then is to become involved in the forecasting question. Again referring back to Dr. Barney's study, he points out that quite often high level policymakers are not aware of what instructions are in an existing model, quite often have not met the modelers in their agency; yet take the results that come out of the model and deal with those. So we are trying to improve that.

Senator MATHIAS. Does this group address the followup to Global 2000?

Mr. HILL. That will be our ultimate project. We have to go through this phase of forecasting, and then we will make suggestions to the Cabinet Council and to the President.

Senator MATHIAS. And is this related to the review of Global 2000 in any way that Secretary Watt described?

Mr. HILL. We have discussed that with Secretary Watt with no final decisions yet.

Senator MATHIAS. Discussed his——

Mr. HILL. Discussed his involvement.

Senator MATHIAS. I suppose my question is, is his review of Global 2000 an independent effort, or is it encompassed in the——

Mr. HILL. It is encompassed in this——

Senator MATHIAS. In the Interagency Global Issues Working Group.

Last December you were visiting the House of Representatives and you told the Energy and Commerce Committee that you were planning to create, in addition to the Global Issues Working Group, a technical forecasting team, drawn again from people already in the Government, as I understand it.

Mr. HILL. Yes.

Senator MATHIAS. These people have experience with the Federal modeling capability and know what is wrong with it as well as what is right with it, and would be your advisers.

Now, has that project moved along from that?

Mr. HILL. That is what will flow from this next phase we are entering now. As I said, it begins with Dr. Barney's presentation on his report and an opportunity for questions and answers.

Senator MATHIAS. It is somewhat ironic that you should be testifying while the Senate is over debating the budget because as you testify here, the funds available for acquiring high quality, highly accurate information are being cut.

I am not asking you to comment on the question of economy in Government or balancing the budget or any of those subjects, but recently OMB eliminated what was already a very small Statistical Policy Branch which is required by the Paperwork Reduction Act to coordinate Federal statistical policy.

Now, how will these budget cuts and this OMB action affect the Federal Government's foresight capability?

Mr. HILL. I have not discussed that with our representative on the working group from the Office of Management and Budget so I cannot respond at this point.

Senator MATHIAS. I would appreciate it if you would keep us in touch with that because it seems to me that as we go down through the end of this century, the need for this kind of information is going to be so much greater. The complexity of our society is greater, and

therefore we have to tread our path much more carefully than ever before in history. I would appreciate, and I think other members of the committee would appreciate, being advised as to just where we are in all of this, and if our capacity to acquire information is going to be so limited that it becomes a damaging loss to the Government, we ought to know it and we ought to try to take some remedial action before the damage is done.

So, I am well aware of the restraints upon members of the executive branch appealing directly to the legislative branch, but there are always ways of communicating, and I hope you will not neglect them.

You were in Nairobi at the United Nations Conference last month, and I am wondering what questions were asked of you there about the Global 2000 Report or about the forecasting capability that you have been describing to us. Is there any interest in that in other nations around the world?

Mr. HILL. I had some extensive discussions with representatives of the Japanese Government, including the sitting environment minister and his predecessor who visited me here in December and went home and was fired 3 weeks later. The Japanese are very interested in the Global 2000 study. Interestingly, the Spanish language translation of the document was released at Nairobi. We have not had one as yet. I know there are several other language translations. The Federal Republic of Germany Government has proceeded. Their parliament, their Bundestag devoted an entire day to debate and discussion of this. We had some brief conversations with the Germans. They are looking to technology to solve many of the problems that they perceive. Other governments have taken a look at this. The Japanese are especially interested and have put forward a proposal for a high-level expert commission that was sent to the governing council of UNEP, which asked the executive director to review the proposal and report it at the next governing council meeting in 1983.

Senator MATHIAS. I hope we can learn from our own experience with the Japanese. They have taken American principles of productivity and American principles of quality control and used them to such advantage that they are driving us out of the marketplace in a great many industrial areas.

So if they perceive some value and utility in the Global 2000 Report which has been, I think, to a large degree neglected in the United States, more neglected than it should have been, perhaps we ought to be reading the tea leaves in Japan.

Mr. HILL. I agreed with the then-environment minister to set up a staff contact and exchange information with the Japanese Government as they are working on their review and proposal for the future.

Senator MATHIAS. I have just one last question for you. Several years, ago, during an interregnum out at Langley, I asked one of the wisest men in Washington what he felt was the most important qualification for the Director of the Central Intelligence Agency. His answer was very brief. He said that the President of the United States should enjoy having coffee with him at 7:30 in the morning. [General laughter.]

I think it is a very accurate and very thoughtful response because you can spend billions of dollars collecting data out at Langley, but if the decisionmakers who need to use it do not absorb it, you have thrown all the money and all the effort away.

Now, the same question really could be asked of you on global modeling and global forecasting. What thought have you given to marketing this product? What consumer resistance have you encountered?

I would say offhand that you have consumer resistance from Secretary Watt on Global 2000.

Mr. HILL. There is concern about what some call the gloom and doom tone of Global 2000. There is concern such as is that based on factual data.

Senator MATHIAS. Whether the assumptions are correct.

Mr. HILL. I neither support nor oppose their criticisms or their praise for Global 2000. I think it was an essential and a good first step. We should recognize it for that.

When I formed this working group, it was with White House approval and support. I would not have gone ahead and done that without that approval. So we are in the normal decisionmaking process.

Senator MATHIAS. I hope you really give some thought to how to reach the consumers with this information because personally, I think it is important. You probably ought to realistically recognize that you have more consumer resistance than just James Watt. There must be other people scattered around.

Mr. HILL. Oh, yes.

Senator MATHIAS. I want to enlist your service in trying to overcome that and in trying to do anything that I can to persuade people that they had better find out what there is to know about what is facing us in the world and that we have some capacity to do that, and that we can avoid mistakes if we do it; at least to look at the alternatives.

Maybe we do not know precisely what to do, but at least we can make an intelligent choice among alternatives. Anything that we can do to soften up the market I am available to help on. If the decisionmakers do not use the product, you have wasted your time.

Mr. HILL. That is correct.

Senator MATHIAS. Thank you for being here.

Mr. HILL. Thank you.

Senator MATHIAS. The committee is adjourned subject to the call of the Chair.

[Whereupon, at 12:48 p.m., the committee adjourned, subject to call of the Chair.]

APPENDIX

Prepared Statement of Hon. George E. Brown, Jr., A Representative in Congress from California

At the outset, I would like to commend the Chairman and the Members of this Subcommittee for holding hearings on this topic. In my years in Congress, I have become increasingly concerned about the decisions which we are forced to make here without adequate information about the longer-term effects or global impacts of those decisions. We scurry from crisis to crisis, dealing with the immediate need and ignoring the cumulative future effects of these individual actions. Rarely do we take the time to conduct foresight hearings, such as these today. I hope that other Committees of Congress follow the example that you are setting today.

We are in a period of extreme change. Political relationships, economic patterns, natural resource levels, and many other sectors are in a state of flux. This rapid change strains our decision-making process, which is largely reactive. In these periods of rapid change, we become reactionary, using past approaches to deal with present problems. Only by being adequately armed with good information about where events will lead us can we break out of this potentially disastrous situation.

Our forecasting and modeling systems are one way to improve our performance. I would like to commend the Office of Technology Assessment for their study, Global Models, World Futures, and Public Policy, for shedding some light on this topic. Their report should be read by anyone seeking to improve government performance in making complex policy decisions.

This government's latest major effort at forecasting, the Global 2000 report shows both the promise and limitations of modeling systems. This report attempted to integrate a number of data bases and then run a forecast out for the next twenty years. Its conclusions came out in the same range that a number of other global models have produced. It should be viewed, along with other similar studies, as a good start at allowing the future to have equal weight with present events in making policy decisions.

The report had a number of shortcomings as well, which serve not as an indictment of this particular study, but rather as a warning of the inadequacies of our efforts to make sound policy decisions. As an example, land use data was collected from a number of federal agency plans. However, this data could not be adequately integrated because each agency was planning for a different use for the same plot of land. Without government-wide integration of this data, we are working in the dark. We might make a policy decision on a particular use for a piece of land, only to find years later that this decision precluded a higher value use of that land. This is but one simple example of the larger problem which exists.

We are being surprised by change, rather than taking advantage of it. Some of our political and economic competitors are reaping the benefits of a much enhanced forecasting effort, and we are the losers, Pasteur said, "Chance favors the prepared mind," and we, unfortunately, are not yet prepared. We should be putting more effort into long-range planning and forecasting. We should be paying more attention to institutions such as the Office of Technology Assessment in making our policy decisions. And we need to conduct more foresight sessions, such as this one, to integrate the information which is available to us.

Again, I appreciate the efforts of this subcommittee and the opportunity to address this issue.

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